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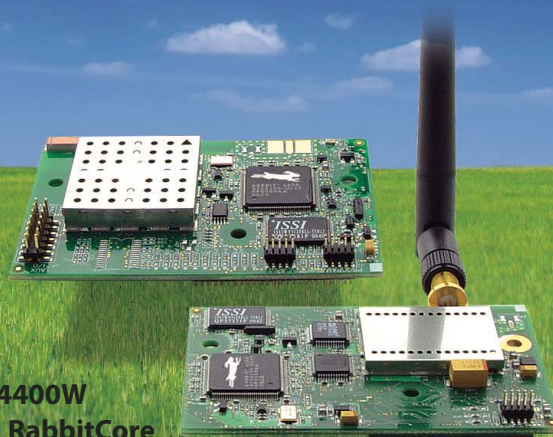
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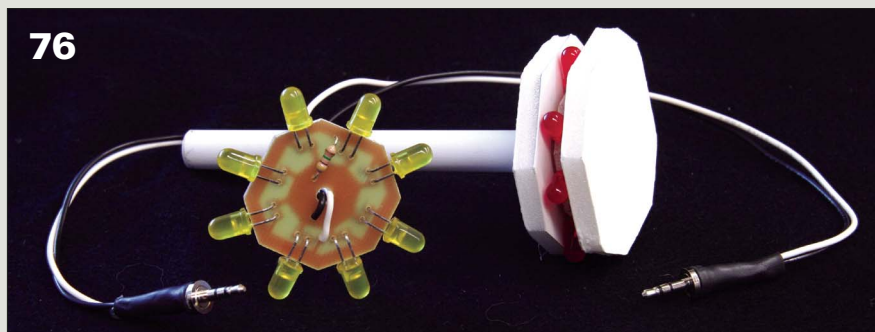
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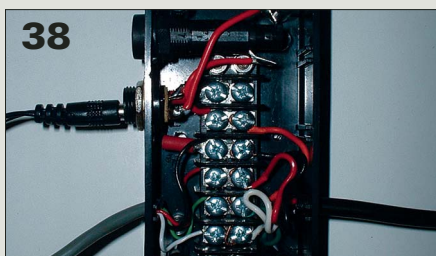
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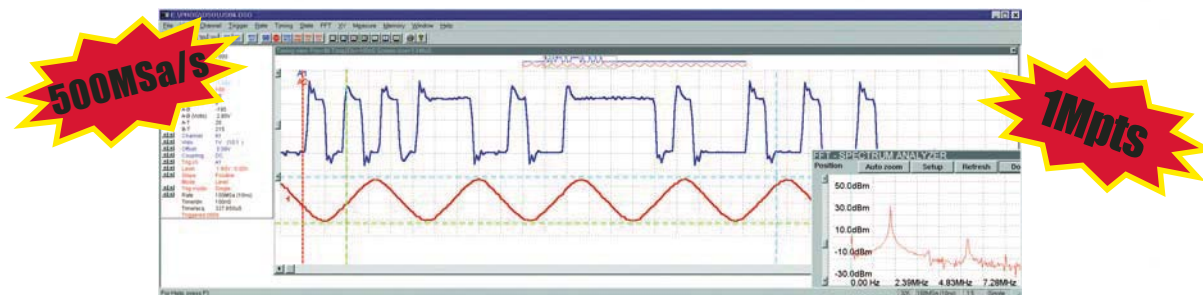
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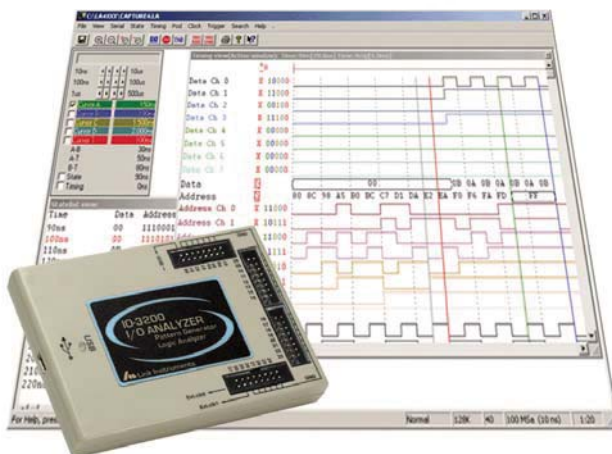
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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

Most of the projects described in *Nuts & Volts* deal with sensors, actuators, and other electronic devices that are separate from the user — benchtop instruments, robot vehicles, home automation appliances, and the like. However, it's important to note that many of the technologies behind these devices — such as Michael Simpson's Wireless Weather System or Rodney Reitan's Remote Voltage Monitor in this issue — are applicable to the field of wearable computing.



Wearable sensors, computers, and output devices are more common — and have been around longer — than you might think. Consider the cuff links and watch in the photo. Each cuff link is a functional magnetic compass. The watch not only shows the passage of time, but displays compass heading, altitude, temperature, ambient atmospheric pressure, and the pressure trend for weather prediction. The analog compasses are fairly accurate magnetic sensors, and the watch has considerable computing power assigned to interpreting onboard sensors.

If you're into cardiovascular fitness, you may have a heart monitor watch that's wirelessly linked to a chest-strap electrode. The system measures your heart's electrical activity and calculates an equivalent pulse rate. The better monitors can download data wirelessly to a PC for plotting and analysis. Some manufacturers, such as Nike and Adidas, build heart rate sensors and/or sensor sockets into their athletic clothing. At the high-end of the wearable computing are military vision systems that combine ambient light images with night vision images overlaid with compass heading to provide soldiers with a better sense of surrounding threats.

The mainstream commercial and military personal sensing and wearable computing products provide a mere glimpse of the economic and functional potential of the underlying technologies. In research labs, prototype shirts laced with conductive threads enable the musically inclined to play a virtual keyboard by tapping on their shirt sleeves. Textiles with built-in LEDs enable wearers to create custom T-shirt displays — and then change them as easily as they switch songs on an iPod. Body area networks enable communications between disparate wearable devices, and haptic radar headbands can help the visually impaired avoid unseen objects.

What will it take for these and other wearable computing devices and technologies to move from the research bench to the market? The hurdles include:

- Identifying the best user interface for a given device and/or task.
- Creating fabrics with built-in sensors and displays that can withstand the rigors of regular use (recall George Jetson's 'indestructible suit' that had to be dry cleaned).
- How to train wearable computer systems so that they perform as expected.
- Identifying applications that have value beyond the initial novelty.

This is where you come in. You may not have the facilities to create conductive fabrics with built-in computing elements, but if you have access to a PC, you can experiment with machine learning algorithms and other methods of training wearable computers. Furthermore, identifying application areas and optimum user interface designs are exercises in imagination that anyone can address. So, put on your thinking cap — and then share your result with other readers. I look forward to hearing from you. **NV**

RESOURCES:

- IEEE Pervasive Computing Journal, www.computer.org/portal/site/pervasive
- International Symposium on Wearable Computing, www.iswc.net
- MIT Media Lab, www.media.mit.edu/wearables
- Wearable Computer Lab, www.wearable.ethz.ch
- Wearables Central, wearables.blu.org

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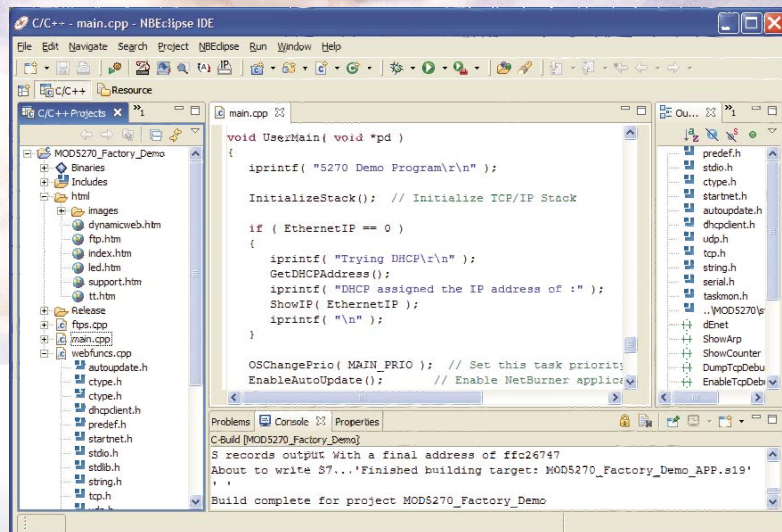
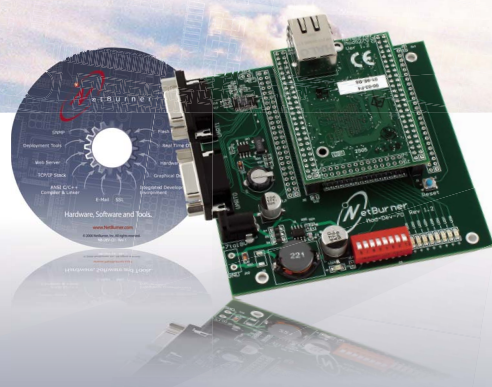


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READER FEEDBACK

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EVERYTHING FOR ELECTRONICS

CRYSTALS ON THE CHEAP – NOT!

First, let me congratulate you all on the very fine job you did on my BINGO project in the Oct '07 issue. Looks really great!

Second, a small anomaly has snuck in (Murphy is always on the job it seems!).

The article reads on page 54, item "B":

B) RC_osc tells the PIC a resistor-capacitor combination will be used to run the PIC clock (if desired, a crystal oscillator can be used for PIC oscillators to reduce costs).

My original text read as follows:

B) RC_osc tells the PIC a resistor-capacitor combination will be used to run the PIC clock (A crystal, often used for PIC oscillators, was not used to reduce the cost of the project).

Unfortunately, the wording in the magazine leads readers to believe it is CHEAPER to use a crystal for the oscillator and that is exactly

opposite to the truth.

— Chuck Irwin

CNC'ING IT DIFFERENT

Dear Mr. Weikle:

I was very sorry to hear that you were disappointed with the Jul '07 Nuts & Volts article "Introduction to 3D Scanning" by Dan Mauch. Until now, the comments have been quite positive.

Please allow me to state that we are excited about 3D scanning and wish to express that our article's basis was directly related to prior feedback that we have received. Many people contacted us back in 2005 requesting details about 3D Circumference Scanners, the technology, hardware, and scan process. This article was an overview of those elements.

I am sure that you have gathered in your research on the subject of 3D scanning that the number of methods are wide and that it usually requires the combination of several complex technologies to work. In particular, when it comes to optical methods, it's not something that would fit in a single article.

If there is something specific about 3D scanning that you would like to

Continued on page 97

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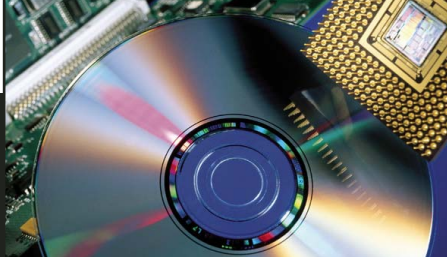
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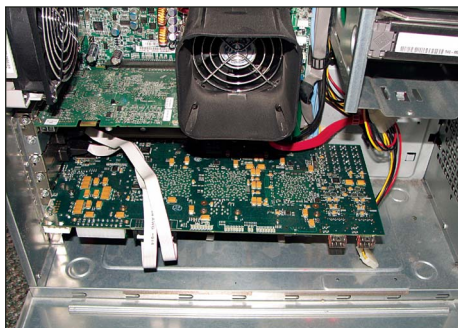
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■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

DESKTOP SUPERCOMPUTER DEVELOPED



■ Uzi Vishkin's prototype desktop supercomputer.

PHOTO COURTESY OF CLARK SCHOOL OF ENGINEERING, UNIVERSITY OF MARYLAND.

For many years, the computer industry relied primarily on chip fabrication improvements to produce higher and higher clock rates, thereby keeping Moore's Law alive. But physical limitations have begun to kick in, and it looks like the best way to achieve greater computing power is through parallel processing. This is exemplified by the newer dual- and quad-core processors that are appearing in PCs, but it appears that Professor Uzi Vishkin, at the University of Maryland (www.umd.edu), has leapfrogged ahead of the game.

Vishkin and colleagues at UM's A. James Clark School of Engineering have developed a prototype machine that uses 64 parallel processors, thus promising to provide speeds 100 times higher than current desktops. Vishkin has actually been working on the concept since 1979, when he began developing a theory of parallel algorithms that relied on a mathematical model of a parallel computer (at the time, no viable parallel hardware existed).

By 1997, advances in technology enabled him to begin building a prototype desktop device to test his theory, and it was completed in

December 2006. He kept it under wraps until recently but finally, based on positive reactions from graduate students and others, decided it was time to let the world in on it.

For example, according to Charles E. Leiserson, professor of computer science and engineering at MIT, "The single-chip supercomputer prototype built by Professor Uzi Vishkin's group uses rich algorithmic theory to address the practical problem of building an easy-to-program multicore computer. Vishkin's chip unites the theory of yesterday with the reality of today." Vishkin believes that his approach (on which he holds several patents) will eventually lead to a revitalization of the computer industry.

FISH AND LEDS SMELL IN THREE DAYS?



PHOTO COURTESY OF US GEOLOGICAL SURVEY.

■ This grumpy-looking Chinook salmon perhaps suspects his fate.

As reported here from time to time, there is a continuing quest for brighter LEDs. It now appears that, in collaboration with the US Air Force Research Laboratory (www.wpafb.af.mil/AFRL/), Professor Andrew Steckl of the University of Cincinnati (www.uc.edu) has come up with an interesting (and somewhat distasteful) new approach.

As we know, an LED emits a photon whenever negative and positive charges recombine in the P region of the semiconductor. But some of the

electrons passing through the device fail to find a positive mate and are therefore wasted. A challenge has been to find a better way to manipulate the electron's mobility so as to trap them longer and give them more time to latch onto a positive charge.

In his search for cheap, plentiful materials that can be used for such purposes, Steckl has discovered salmon DNA. To be specific, salmon sperm. He noted, "Salmon sperm is considered a waste product of the fishing industry. It's thrown away by the ton. It's natural, renewable, and perfectly biodegradable."

The result is devices dubbed BioLEDs, which incorporate DNA thin films as electron blocking layers. Standard devices use inorganic materials such as silicon but, according to Steckl, DNA's unique properties allow two orders of magnitude improvements in efficiency and brightness. Research continues, with the long-term goal of making "green" devices that use only natural, renewable, and biodegradable materials.

The professor's work seems to be generating considerable interest. "I'm receiving salmon sperm from researchers around the world wanting to see if their sperm is good enough," he observed. While Steckl is currently focusing on salmon, he thinks that other animal or plant sources might be equally useful, so keep your dogs and cats inside at night.

COMPUTERS AND NETWORKING

AI LAB BATTLES TERRORISM

Many recent news features (and legal controversies) have focused on passive monitoring of communications between suspected

terrorists. But a more aggressive approach has been adopted by the Artificial Intelligence Lab at the University of Arizona (ai.arizona.edu), where the Dark Web project has been instituted to find, catalog, and study these virtual places where terrorists and extremists operate.

The project is funded by the National Science Foundation and headed up by lab director Dr. Hsinchun Chen. This is no minor undertaking, given that there are an estimated 5,000+ websites created and maintained by known international terror groups. But using advanced techniques such as spidering, link analysis, content analysis, authorship analysis, sentiment analysis, and multimedia analysis, Chen and his team keep track of extremist activities online and use advanced computers and applications to find patterns and connections that humans cannot detect.

One of the tools developed by Dark Web is Writeprint, which automatically extracts thousands of multilingual, structural, and semantic features to determine who is creating "anonymous" content online. According to the team, it can determine with 95+ percent accuracy if the author has produced other content in the past. The system can then alert analysts when the same author produces new content and track where on the Internet the content is being copied, linked to, or discussed.

Dark Web also uses spiders to search discussion threads and other content. The program is subject to sabotage, of course, and the spiders occasionally bring back viruses that are designed to attack its operation. But it appears to be generating positive results. For example, Dark Web just completed a study of online materials designed to train terrorists in the production of improvised explosive devices (IEDs). The information gained will be used to develop more effective countermeasures. "What we are doing is using this to study societal change," Chen observed. "Evidence of this change is appearing online, and computational science can help other disciplines better understand this change."



CHEAP BUSINESS SERVER INTRODUCED

If you run a small business and have been using low-cost PCs as servers to keep costs down, you might want to take a look at the new PRIMERGY Econel 230R S1 from Fujitsu (www.computers.us.fujitsu.com). Designed as an entry-level rack-mount server for small enterprises, the machine features the dual-core AMD Opteron™ processor plus the improved reliability and storage capacity needed for a stand-alone application, web, or terminal server.

To help keep data secure, the machine offers error checking and correcting (ECC) memory protection and integrated RAID disk mirroring, and the "easy change" design facilitates the installation and replacement of memory, hard drives, etc. It features one or two processors running at up to 2.4 GHz, up to 16 GB of main memory, and four PCIe and PCI-X slots. The basic configuration will set you back only \$1,654.

CIRCUITS AND DEVICES

VINYL TO DISK MADE EASY

Okay, I admit it. A significant portion of my garage is dedicated to a huge collection of vinyl LPs left over from ancient college days. They are unappealing to the cockroaches, annoying to the wife, and haven't been played in years. And yet, somehow, I can't bring myself to dispose of such lost gems as Crow's "Mosaic" and Roland Kirk's "Case of the Three-Sided Dream in Audio Color."

It has long been possible to assemble a collection of cables and adaptors to port turntable output into a PC, but it has not been all that convenient, and noise generated by crud in the grooves was not easy to remove. But the procrastination can now come to an end via the model GT-USB belt-drive turntable from Gem Sound (www.gem-sound.com).

■ The GT-USB turntable offers a USB audio interface.

PHOTO COURTESY OF GEM SOUND CORP.



PHOTO COURTESY OF FUJITSU COMPUTER SYSTEMS.

■ Fujitsu's Econel 230R S1 — a server for penny pinchers.

It includes Audacity™ sound editing software (PC and Mac compatible), Soundsoap SE software for removing the clicks and pops, support for both 33 1/3 and 45 RPM playback (and even 78 RPM via software), and an anti-skating control for better stereo balance. The unit is a bit hefty at 10.6 lbs, but it's pretty cheap by those pounds. You can pick one up on the web for as little as \$104.99.

NEW CMOS CHIP TO SIMPLIFY MOBILE DEVICES

IBM (www.ibm.com) recently announced a new semiconductor technology that will enable chipset providers for mobile devices to reduce the complexity of their components, which will allow significantly lower manufacturing costs for the next generation of mobile phones, laptops, and other communication devices. Called CMOS 7RF SOI, it integrates multiple RF and analog functions (e.g., multi-mode/multi-band RF switches, complex switch biasing networks, and power controllers) into a single chip.

IBM speculated that as the technology evolves, it could also include filter, power amplifier, power management and receiver/transmitter functions. Cost savings are also realized by replacing expensive gallium arsenide (GaAs) components with CMOS.

Reportedly, the electronics in a standard mobile device now cost about \$20 to manufacture, and the new technology will reduce that by about \$1 per unit. Initial hardware evaluations are now complete, but design kits will not be generally available until the middle of 2008. The first handsets incorporating the technology should appear sometime in 2009.

YEAH, RIGHT

For those who are bald and desperate, let us introduce the HairMax

LaserComb, developed in Australia, manufactured here, and available at www.hairmax.com. Earlier this year, the device received FDA approval, which is often (and incorrectly) interpreted to be an endorsement of its efficacy. In reality, it is a Class II medical device, and there is no individual FDA evaluation of this class. Having said that, we note that the marketer (Lexington International) claims that 93% of participants in clinical trials reported positive results,

with the average number of terminal hairs per square centimeter increasing by 19 over a six-month study.

The theory is that the low-level laser treatment increases blood flow to the scalp and follicles, thus encouraging hair growth. Does it work? Well, for only \$545, you can buy one and find out. Or you could buy a \$1.99 hairbrush at Wal-Mart, drill some holes in it, and insert a few laser pointers. **NV**

INDUSTRY AND THE PROFESSION

PACEMAKER 50 YEARS OLD

■ Earl Bakken, wearing his Russ Prize medallion, displays his famous pacemaker. Thanks to the Bakken Library.



In case you didn't notice,

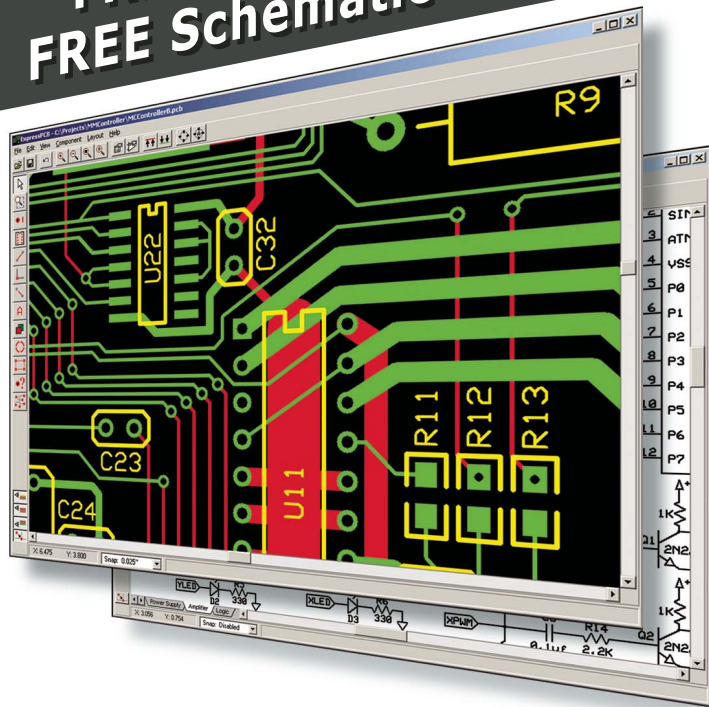
2007 marks the 50th anniversary of the invention of the first wearable, external, battery-powered, transistorized pacemaker. It was invented by Earl Bakken, who co-founded Medtronic, Inc., which remains the world's largest manufacturer of cardiac pacemakers. In 2001, Bakken was awarded the Fritz J. and Delores H. Russ Prize by the National Academy of Engineering and Ohio University (Russ's alma mater), which included a tidy \$500,000. He retired from Medtronic in 1989 and moved to Hawaii, but still visits from time to time. For more information, visit www.thebakken.org or pick up a copy of his book *One Man's Full Life*.

LOTS OF TINY SPEAKERS

Among the things we take for granted are the tiny speakers built into mobile phones and other portable devices, but to NXP Semiconductors (www.nxp.com), they are no small thing. The company, formerly a part of Philips, has announced that it will invest 42 million Euros in its Sound Solutions facility in Vienna, Austria, before the end of the year. NXP already has nearly one third of the world market in this sector and has shipped more than two billion speakers. Its latest units, at 10 x 4.8 x 2 mm, are among the smallest available. NXP expects to sell approximately 550 million sound components this year alone, and the investment will help ramp up manufacturing capacity.

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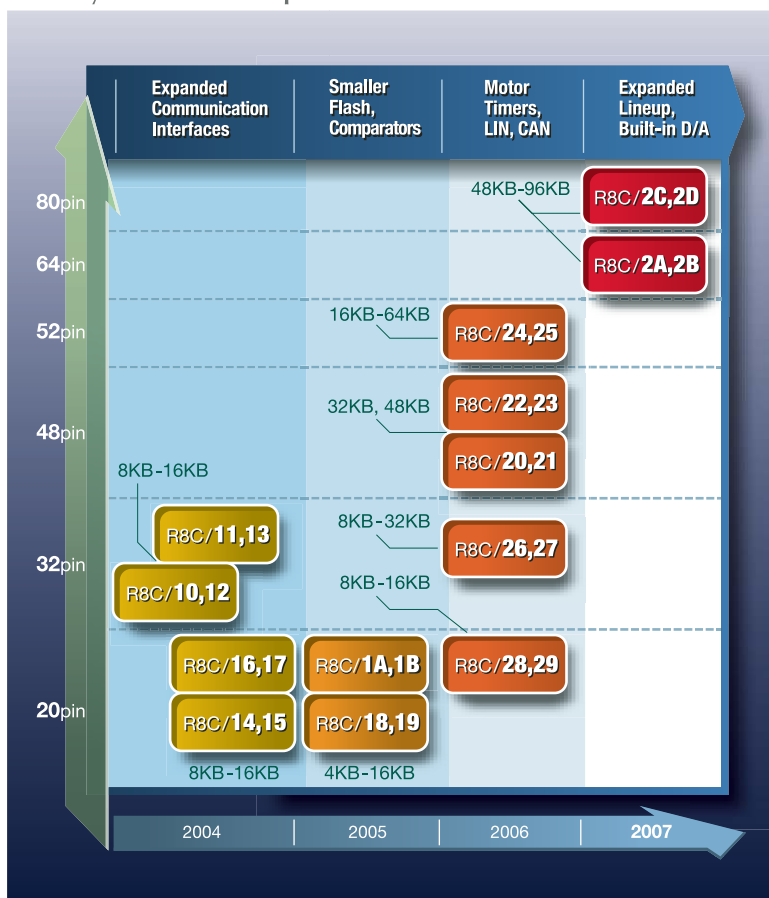
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R8C/Tiny Product Roadmap



*Source: Gartner Dataquest (April 2006) "2005 Worldwide Microcontroller Vendor Revenue" GJ06333

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■ BY JON WILLIAMS

DIMMING THE LIGHTS FANTASTIC

WOW ... IT IS, ONCE AGAIN, THAT TIME OF YEAR; the time of year where the air is crisp, the colors are vibrant, and holiday lights decorate neighborhoods across the country. It seems like — in my suburban Los Angeles neighborhood, anyway — that November 1st has become the official start of the Christmas decorating season. Well, that's okay by me, especially after bumping into Vixen a few months ago. You may remember that back in May we used Vixen as an animatronics controller. This month, we're going to build an eight-channel lighting dimmer that can be controlled with Vixen, or a BASIC Stamp, remote SX, or even a Propeller processor if we like.

Lamp dimming — specifically 120 VAC lamp dimming — had been on my mind for quite a long time, and this year I finally jumped in and tackled the process. It started with a four-channel device called the FC-4 that I designed for EFX-TEK. My friends who are Christmas enthusiasts asked that I create a similar device that could be expanded to 64, 96, or even 128 channels; that's what this month's project is all about. The controller has eight dimming channels and is addressable so that 16 boards can happily co-exist on the same link; this gives us 128 dimmable channels; probably enough for most home lighting displays.

AC CONTROL

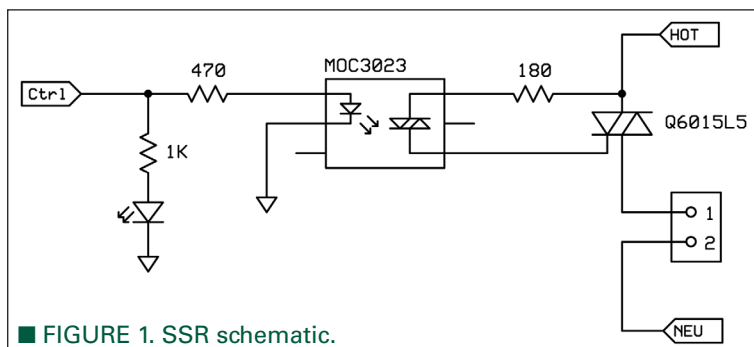
As this project is a bit involved, let's just jump right in. We'll start with switching AC using a digital circuit. Many of us have used mechanical relays to switch AC, but they're noisy and can arc, ultimately forcing us to replace the relay due to contact pitting (or worse, contact fusing) — and mechanical relays have only two states: on and off. The advent of the solid-state relay is a boon to those of us that

want to switch AC with digital circuits. Crydom is a popular manufacturer of solid-state relays providing devices that can take a direct TTL input signal and switch voltages from 12 to 230 VAC at several tens of amperes.

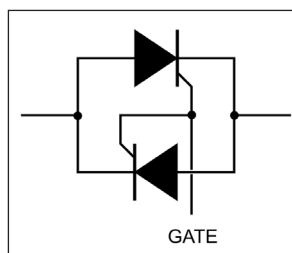
For Christmas tree lights, we don't need to switch that much current; this means we can create our own solid-state relay circuit. Figure 1 illustrates a very common circuit used to switch AC with a TTL control signal. Note that there is optical isolation between the control and output sides — this is very important for safety.

A TTL high on the control pin will cause the LED in the MOC3023 to light which, in turn, causes the triac side of this device to conduct. This allows the output power triac to be gated and conduct — the triac acts like a switch in the AC line between hot and neutral. When the control signal is removed and the AC voltage hits the zero-cross point, the output triac will shut off.

That last point is very important to understand, especially when it comes to lamp dimming. A triac is a solid-state switch that is designed for AC circuits. It's convenient to think of a triac like two head-to-toe SCRs connected together with a common gate, as in Figure 2. When the gate signal is applied, one side or the other will conduct (two sides are required for AC). When the gate is removed and the voltage passes through zero, the triac will shut down. This SCR-like (self-latching) behavior is the reason you can't switch DC with a triac — well,



■ FIGURE 1. SSR schematic.



■ FIGURE 2. Triac construction.

more accurately, you can switch DC on but you can't turn it off without removing power.

AC LAMP DIMMING

If a triac stays on until the gate is removed and voltage passes through zero, how do we use it as an element in a dimmer circuit? What we have to do is monitor the AC voltage for the zero-cross and then gate the triac sometime after, and within the same half cycle. If we gate the triac about half-way through one half of the AC cycle, a lamp connected to this output will be at about 50% brightness.

Figure 3 illustrates an AC waveform showing the zero-cross points; there are two per cycle, so our dimmer control circuit will actually fire the triac at a 120 Hz rate. The blue area under the curve indicates the time when the triac is conducting. Note the hold-off period; the shorter this period, the brighter the lamp will light.

As you might expect, we'll use another opto-isolator to monitor the power line for zero-cross. Figure 4 shows a circuit that I've seen used in many home-brew lamp dimming circuits and it works quite well. The output on the ZC line has a high-going pulse every 8.333 milliseconds (120 Hz) that occurs very near the zero-cross (it actually straddles the zero-cross point as the LEDs in the H11AA1 have a 1.2V forward voltage). Our program will use this pulse to start the hold-off timer for each dimming channel.

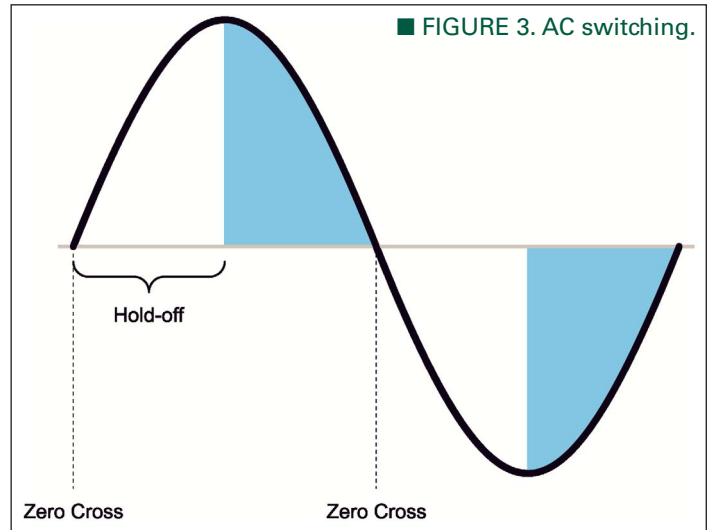
In order to control eight dimmers and get their values from an external device via serial input, we will construct an ISR (interrupt service routine) that handles the receive UART and the dimmers. I selected 38.4 kBaud for the input as this lets us refresh 128 channels in under 50 milliseconds (good for zippy displays), and the math works out pretty cleanly: With a 26.042 μ s bit time, we need to run the interrupt every 6.51 μ s in order to do 4x sampling of serial bits. Fortunately for us, 6.51 will divide cleanly into 32.55 μ s which is 1/256th of each 60 Hz half cycle. This allows us to set channel brightness with a byte, and as it takes a full byte, we can do a little code trickery to construct the hold-off period.

Within the ISR, we'll have a divider that runs the dimmer processing every fifth cycle. It looks like this:

```
Check_Dimmer_Tix:
ASM
    BANK    dimmerTix
    INC     dimmerTix
    CJB     dimmerTix, #5, Dimmer_Done
    CLR     dimmerTix
```

This is pretty easy — we increment *dimmerTix* and when it hits five, we will process the dimmers (resetting *dimmerTix* before we do). If you haven't jumped in to SX assembly, let me encourage you to give it a try. Honestly, I'm a poster boy for the purpose of SX/B: to help BASIC Stamp users migrate from Basic only to mixed and assembly-only projects. Remember that SX/B compiles to straight assembly, so you can always write something in Basic and look at the compiled output to see how the

■ FIGURE 3. AC switching.



translation is made. Using this very process, I have been adding a lot of assembly segments to my programs where absolute efficiency is key; you can, too.

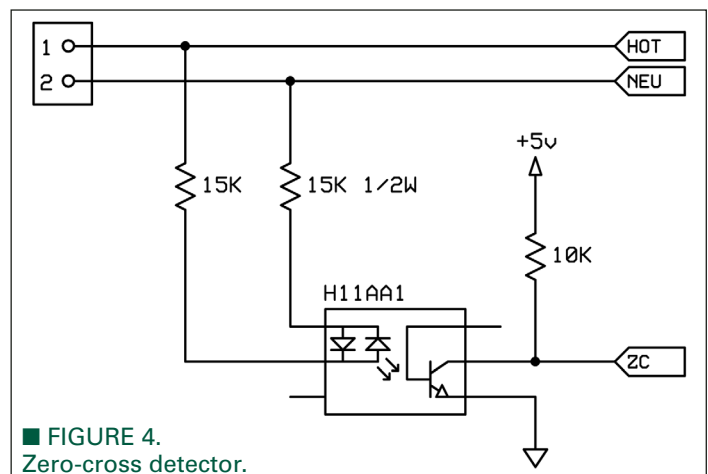
Okay, now that it's time to process the dimmers, what we need to do is check to see if we're at the zero-cross point. This is easy: the ZC input pin will be high if we are. Let's assume that's the case and that we're at the beginning of a new half-cycle.

```
Dimmer_Service:
    BANK    dimmer
    JNB     ZCross, Update_Triacs

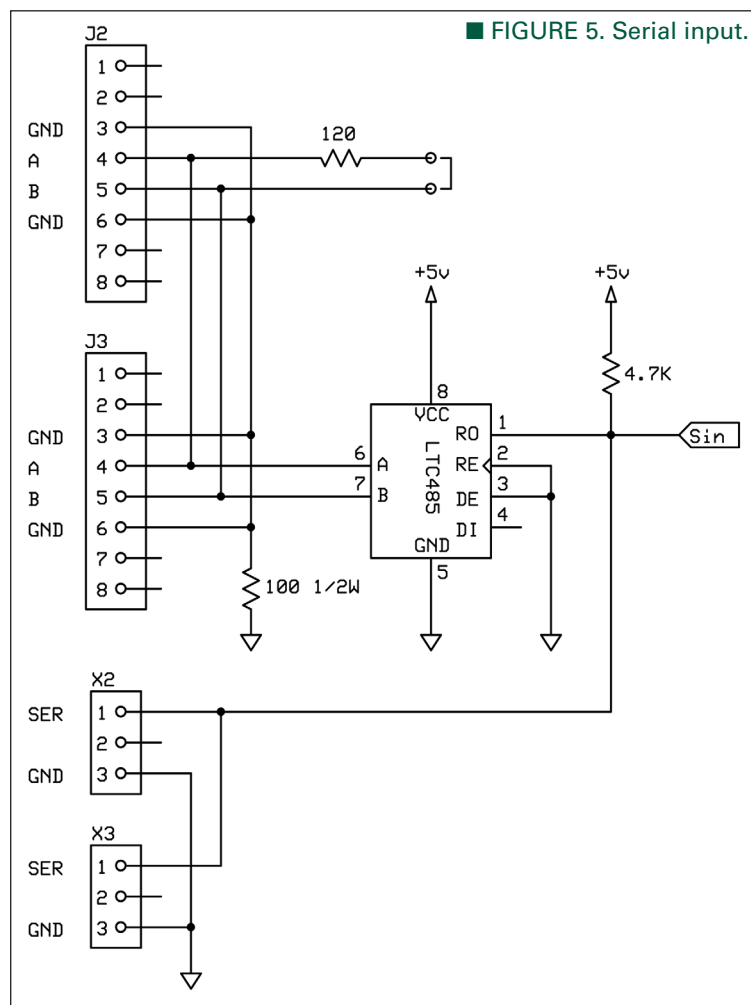
Zero_Cross:
    CLR     Lamps
    MOV     acc1, chan1
    MOV     acc2, chan2
```

At the zero-cross point, the program clears all of the triac gate control pins (on port RC). Then, the current brightness level for each channel is reloaded into an accumulator for that channel. Note that I'm only showing two channels above, but the program actually has eight.

Okay, now for the fun stuff. The program uses a PWM technique that is very clever and dirt simple to implement.



■ FIGURE 4. Zero-cross detector.



```
Update_Triacs:
    INC    acc1
    SNZ
    SETB   Lamp1
    INC    acc2
    SNZ
    SETB   Lamp2
```

Each accumulator is incremented and if it rolls over to zero, the corresponding triac gate is enabled. So you see, the higher the channel value, the sooner it will roll over to zero and allow the triac to be gated. And as we saw previously, the earlier we gate the triac relative to the zero-cross, the brighter the lamp will be.

Pretty neat, huh? Yeah, I think so, too.

INTERRUPT FINE TUNING

Being a math wizard, you've probably figured out that with 4x sampling of 38.4K serial bits we should run the ISR at a rate of 153,600 times per second. You're right. Why, then, does the program use the oddball value of 153,826?

Here's the deal ... we're running the SX at 50 MHz which means that each instruction takes just 20 nanoseconds. If we divide 6.51 microseconds by 20 nanoseconds we get 325.5 — whoops, this value is bigger than a byte so it won't fit into the

RTCC register which is what controls periodic interrupts. Remember that the SX/B compiler is very smart, so what it does is set the RTCC prescaler to 1:2; this has the effect of clocking the RTCC every 40 nanoseconds (25 MHz); now the rollover value is 162.7 (which gets rounded to 163).

No problem, right? Well, no, but then what happens is that the dividing up of the AC half-cycle is just a tiny bit out of whack. It doesn't hurt anything, but what we'll see is a very dim control LED when the channel is, in fact, supposed to be off; this bothered me enough to fix it.

Here's what I did: I took the RTCC clock of 40 nanoseconds and multiplied it by 163 (cycles for each interrupt) to get 6.52 μ s. Into this value I divided 6.51 μ s (ideal timing) to get 1.001472 and multiplied that by the initial ISR setting of 153,600 – the final result is 153,826. This eliminates the ghosting on the control output LEDs (off is now off) and does not impact the receive UART as the change is only about 0.14 percent.

The important lesson is that “ideals” are sometimes less than ideal in practical application, and that we shouldn’t be afraid of tweaking to get the best performance from a piece of code.

EXTERNAL CONTROL

This board is designed to be a slave of another device; that device could be a BASIC Stamp on a Board of Education or the PC program Vixen using an RS-485 multi-drop link. The reason for the RS-485 link is to allow significant distance between the PC and the actual dimmer board. We could, for example, use a PC in the back of the house to control one or more of these boards installed in the family room near the Christmas tree.

Figure 5 shows the associated serial connections for the board. For local control (LTC485 chip removed) with a BASIC Stamp, we can use X2 and X3 (for daisy-chaining) and Open-True mode communications. For long distance control, we can use RS-485 (LTC485 installed) serial over standard CAT5 networking cable. I'd love to convince you that I'm very smart and came up with this idea, but I didn't; I "liberated" this idea from my good friend, Peter (who also maintains the SX-Key IDE for Parallax), after seeing it in use in his modular animatronics control system (see www.socalhalloween.com). CAT5 cable works well because it uses twisted pairs and is designed for much higher data rates. In Peter's system, he actually carries DC power (12 volts) to his boards through the cable, as well.

The RS-485 interface is standard, and is set up for receive only. A jumper on the board allows for a 120 ohm terminating resistor as this is required on the final node in an RS-485 chain. Note that the 100 ohm resistor to ground is optional, and only needed if you decide to have common ground between all boards. For more details on this, I recommend Jan Axelson's excellent book, *Serial Port Complete*.

DECODING THE SERIAL STREAM

Like the animatronics controller from May, this project uses a break between streams to synchronize the slaves to

the data within the stream. The process is simple: After a break period of at least one millisecond, the board expects to see up to 16 packets of eight-byte lamp dimmer values. The address of the board determines which group of bytes are plucked from the stream and transferred into the dimmer control registers (*chan1-*chan8**).

The break period is detected by a small section of code in the ISR. Each time through it will increment a counter (*breakTmr*) when the receive line is idle, otherwise, it will clear this counter and the associated flag (*hasBreak*). When the value of *breakTmr* reaches 154 (about a millisecond), the *hasBreak* flag is set and the timer is restarted.

```
Check_Break_Timer:
    ASM
    BANK    0
    JNB     RX, RX_Has_Bit
    INC     breakTmr
    CJB     breakTmr, #BreakCnt, Check_Break_Exit
    SETB    hasBreak
    CLR     breakTmr
    JMP     Check_Break_Exit

RX_Has_Bit:
    CLRB    hasBreak
    CLR     breakTmr

Check_Break_Exit:
    ENDASM
```

Remember that a start bit and zero bit in this system will pull the RX line low, hence the use of JNB (jump if this bit is 0). By installing this code in the ISR, the foreground program can simply look for the setting of the *hasBreak* flag to indicate that a valid break period has been detected.

```
Main:
    breakTmr = 0
    hasBreak = No
    DO WHILE hasBreak = No
    LOOP
```

Once the break is detected, we need to flush the receive UART before proceeding. This seemingly innocuous step caused me three days of headaches trying to track down a “fluttering” problem with my lamps. While I had been clearing the *rxReady* flag, I neglected to clear *rxCount* — this value controls bits coming into the [free-wheeling] UART. What was happening, I believe, is that garbage values in *rxCount* caused misaligned data and corrupted my dimmer values. It was horribly frustrating — I even called Peter to ask him to review my code to see if I was missing something. Sometimes just talking through a problem with a friend can be helpful and I finally determined the problem while explaining to Peter how the program works.

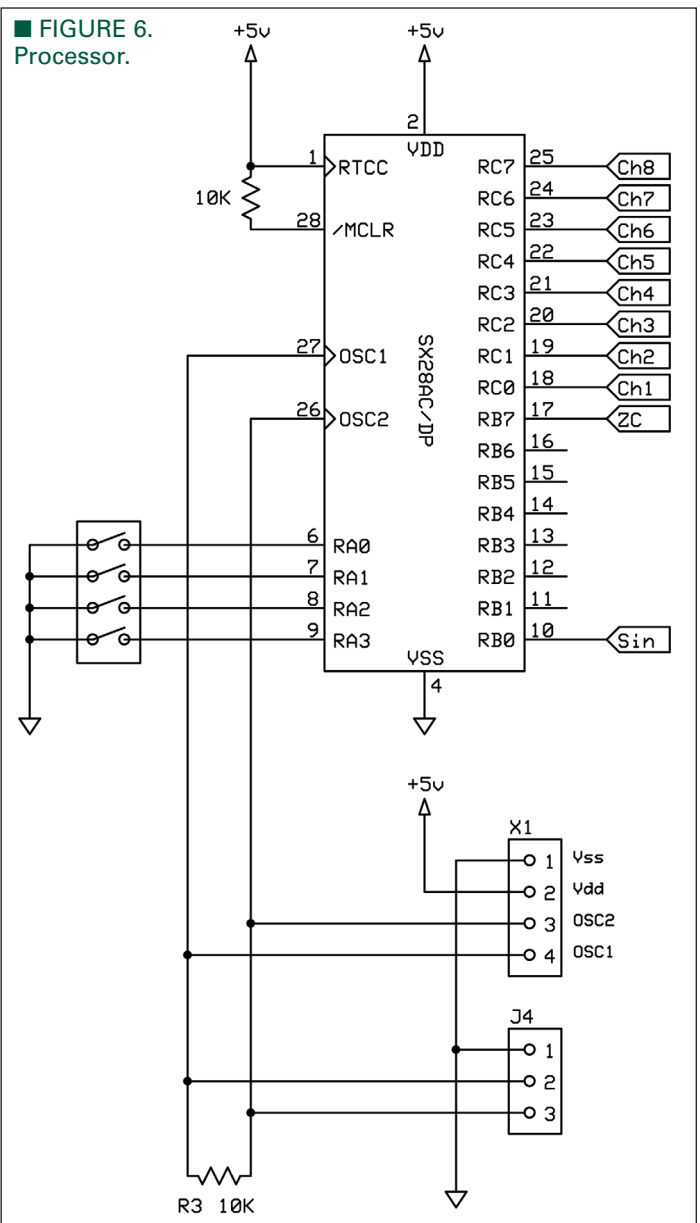
```
Flush_Uart:
    rxCount = 0
    rxReady = No
```

The next step is to read the board address and multiply that by eight so that we know how many bytes in the stream to skip.

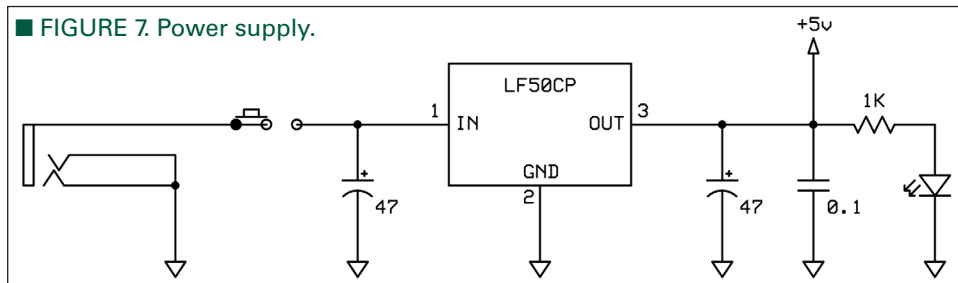
```
Align_Packet:
    idx = 0
    idx.0 = ~Addr.3
    idx.1 = ~Addr.2
    idx.2 = ~Addr.1
    idx.3 = ~Addr.0
    idx = idx << 3
```

This looks like more work than what’s needed; I did it this way to “fix” a board layout issue — what I wanted to do is have the LSB of the switch be to the right so I could read the markings on the SX28. As the LSB switch is actually connected to RA.3 instead of RA.0 (see Figure 6), we manually construct the value to mirror the bits of the address. There may be some chunk of cute code out there to mirror a byte, but this bit-by-bit approach seemed to make the most sense to me. The board address, now in *idx*, is multiplied by eight (<< 3) to determine the number of bytes to skip.

And here’s how we do that:



■ FIGURE 7. Power supply.



Skip_Bytes:

```
DO WHILE idx > 0
  tmpB1 = RX_BYTE
  IF hasBreak = Yes THEN Main
  DEC idx
LOOP
```

Get_Levels:

```
FOR idx = 0 TO 7
  IF hasBreak = Yes THEN Main
  dimmer(idx) = RX_BYTE
NEXT
GOTO Main
```

► PARTS LIST

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► C3	0.1 µF	80-C315C104M5U
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► J1	2.1 mm barrel	806-KLDX-0202-A
► J2, J3	RJ-45	571-5202514
► J4	0.1 strip socket	506-510-AG91D
► JP1	0.1 strip header	517-6111TG
► Jumper	0.1 jumper	535-ME-100
► PCB		ExpressPCB.com
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► R2, R3, R9	10K	299-10K-RC
► R4	120Ω 1/4 W	291-120-RC
► R5	100Ω 1/2 W	293-100-RC
► R6	4.7K	299-4.7K-RC
► R7, R8	15K 1/2 W	293-15K-RC
► R10, R13, R16, R19, R22, R25, R28, R31	470Ω 1/4 W	299-470-RC
► R11, R14, R17, R20, R23, R26, R29, R32	180Ω 1/4 W	291-180-RC
► S1	28-pin DIP	571-1-390261-9
► S2	8-pin DIP	571-1-390261-2
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► U4-U11	MOC3023	859-MOC3023
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► X1	0.1 R/A male header	517-5111TG
► X2,X3	0.1 male header	517-6111TG

Note: All part numbers are from Mouser Electronics (www.mouser.com) unless otherwise noted.

As you can see, this is all very straightforward — as long as *idx* is greater than zero, we'll pull a byte from the receive buffer and just toss it. After bytes start coming in, we can check the *hasBreak* flag again; this will cause the program to jump back to the beginning if the stream gets interrupted.

The final step is to pull our eight bytes into the dimmer control registers. The rest is automatic as the dimmers are already running in the ISR.

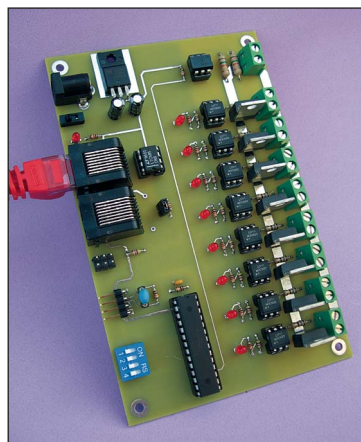
CONSTRUCTION

It would take a very hearty soul to tackle this project using point-to-point wiring — and with 120 VAC involved, let me suggest that you don't. As with other projects, I used ExpressSCH and ExpressPCB to create the PCB for the dimmer. Those of you with a lot of layout experience may find the board a little generous (i.e., it could be smaller); I decided to err on the side of caution considering what's involved.

If you're new to PCB layout and decide to give ExpressPCB a run, let me VERY STRONGLY suggest that you start with ExpressSCH, check it for netlist errors, and then create the PCB by linking to the schematic. What I like about later versions of ExpressPCB is the ability to do flooded planes. The only problem when using a plane with a prototype board (one without solder mask) is that the small spacing between traces and the plane is a magnet for solder bridges. I expand the pad and trace spacing to 0.015" (this is done in the Layout\Board Properties menu), and use a very clean, fine-tipped soldering iron when I work. I also proceed very slowly, checking connections near the plane through a loupe to make sure that I don't have any bridges.

Let me make a very important point about this

project: It involves 120 VAC which can be dangerous if mistreated. Also, prototype PCBs cannot handle large currents, so you should put an inline fuse (5A) on the AC power input (TB1) and ensure that your Christmas light



■ FIGURE 8. Completed Dimmer8x.

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strings are likewise fused. Finally, the whole works should be assembled in a fireproof enclosure using suitable stand-offs from the panel. The holiday season is supposed to be joyous — let's keep it that way.

HAPPY HOLIDAYS

Well, that wraps up this one — order your boards and parts and start building. Whether you use it with

a BASIC Stamp or a big control application like Vixen, I'm sure you'll find this project a lot of fun.

Happy Holidays, and until next time, Happy Stamping! **NV**

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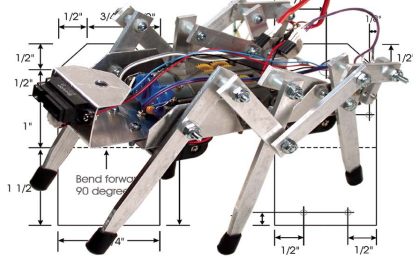
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■ BY VERN GRANER

EVOLUTION OF A ROBOTICIST

RECENTLY, THE GOOD FOLKS AT *Nuts & Volts* asked if I would take on the monthly Personal Robotics column. I was quite flattered. I don't have any formal training as a writer, but I've been writing in the technical arena for many years. I regularly participate on various Internet forums and mailing lists, and my "day job" entails writing RFQ responses, crafting white papers, and building detailed instruction documents for customers. In the few articles I've written so far, I've tried to keep a conversational (and sometimes confessional) tone, including all observations, good or bad. I feel that most projects are not just about the destination, but the journey to success. Sometimes the details about *what* went wrong, *why* it went wrong, and what was done to recover from the failure can be just as interesting (and useful) as the finished project itself.

PLEASE ALLOW ME TO INTRODUCE MYSELF ...

So, with that said, let's get to the point. Hi! My name is Vern Graner. You may remember me from such articles as "The Creation of the Thereping" (*Nuts & Volts* 4/06), "The Train Saver" (*Nuts & Volts* 7/06),

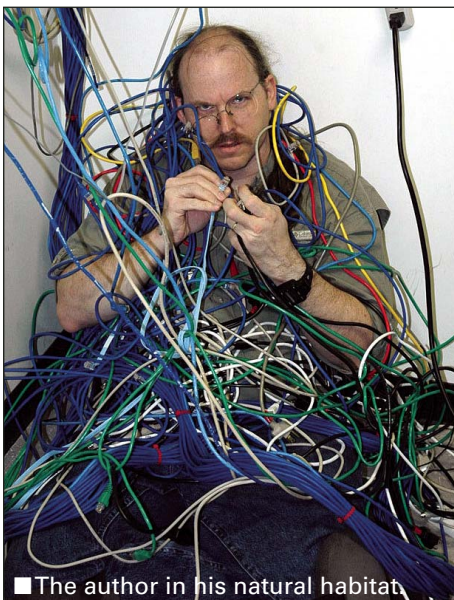
"Recovering our Technical Literacy" (*SERVO* 8/07), and most recently "Evolution of the Boogiebot" (*Nuts & Volts* 10/07). I live in Austin, TX with my wife Kym, two children Nicholaus (age 11) and Samantha (age 5), a dog named Bit (she's black and white), a cat named "Purrbot" (self explanatory), and another cat (ironically) named Mouse. I'm currently the President of The Robot Group, Inc. — a non-profit corporation based in Austin with a fine heritage building robotic contraptions dating back to the late 1980s.

My entire life has hinged around electronics and technology since I was old enough to wonder why a flashlight bulb wouldn't stay lit when you removed the glass globe surrounding it. My mother gleefully recounts how, when I was only eight years old, she received a note from my teacher asking her to "frisk" me in the mornings for motors, batteries, light bulbs, etc. (turns out the small, clumsily wired devices I brought in were distracting the other kids).

I've been an avid reader of electronic hobby magazines and

reference materials (thank you Forest Mimms for the Engineer's Notebooks!) and tried to understand, imitate, and innovate on many of the circuits and schematics depicted in their pages. I have personally reveled in the hard won glow of a working project and have been present (and sadly responsible) for the death of many a component. Have you ever noticed that the "magic blue smoke" released from a reverse-wired, popped electrolytic capacitor has a distinctly different aroma than that of say, burning enamel wire in a shorted power transformer secondary? Then you might be a tech nut ... But I digress ...

Like many of you, I cut my teeth on the requisite build-it-yourself kits offered in those very magazine pages. I built "color organs," assembled Heathkit radios, wound wire around margarine tubs to make crude metal detectors, annoyed my folks (and the neighbors) with PAiA synth kits, and owned every RadioShack "<x>" in 1" electronics kit from the 65 all the way up through 200. And then came computers.



■ The author in his natural habitat.

REMINISCING ON THE REVOLUTION

Computers changed the face of the electronics hobby. I watched firsthand as the "personal computer revolution" stormed the beachhead once securely held by the electronics hobbyists. When I started in electronics, reading schematics and point-to-point wiring was de rigeur. Along came the IC and the printed circuit board and soon enough we had real computers to deal with. The first computer I used was an Apple II at my high school in 1980. I hacked together a keypad from an old calculator to the game port DIP socket on the Apple motherboard to make a rudimentary joystick (my teacher almost had a heart attack!). The implementation was ugly, but it worked. Using computers with my electronics projects from then on was pretty much a given.

Ultimately, the rise of the personal computer led to the rise of the personal robot. I drooled over robots like TOPO, RB5X and, of course, the Heathkit HERO series. As a student with a part time job at a RadioShack, I only managed to own a RadioShack Armatron at the time. Later, I managed to scrape together enough cash to get a Maxx Steele robot, which would eventually don a tuxedo and serve champagne at my wedding

in 1987. But was Maxx a "real" personal robot?

WHAT IS A "ROBOT?"

When I was asked to write the Personal Robotics column, I figured it would be useful to start with a definition of "robot" — i.e., what exactly (other than a popular 1980's dance move) constitutes a "robot?" On the surface, this would seem to be a simple question but I've found it can cause heated debate among hobbyists and professionals alike.

To some, the awe-inspiring, spark-spewing electro-mechanical "Battlebots®" are a perfect example of a robot. Yet some argue these robots are just big radio controlled bumper cars. They contend that a common household dishwasher is more of a robot since it performs automated and reactive functions using microcontroller operated mechanical systems. Still others (the general public, for example) might identify a robot as being anthropomorphic i.e., something like Robby (*Forbidden Planet*), B9 (*Lost In Space*), or even Commander Data (*Star Trek, The Next Generation*). As the author of this column, I guess I need to at least provide my perspective on the issue.

For me, robotics encompasses things people create that sometimes incorporate mechanical mechanisms,

automation, electronics, or computers and are perceived by the creator as being robotic in form or principle. As experience has shown, we are unlikely to achieve consensus on the definition of robot; I think maybe we should focus on the "personal" portion of the title.

I'm hoping that as a personal robotics columnist, I can write about — and for — you. I want to write about the ideas and projects people like you and I create on our workbenches, at our offices, and in our garages. I want to share stories that might interest and inspire you to build something yourself. Maybe begin (or even finish!) that project you've been doodling on napkins and thinking about for the last few months (years?). Entice you to share ideas with others and/or seek out a group of robotics enthusiasts in your area (or on the Internet). Get out there and see what's happening!

END PROGRAM

So enough about me. It's time to hear from you. Please feel free to let me know what you'd like to see in the coming months. I'd love to hear your feedback on what I've written and ideas on what you'd like me to write about. Send your emails and ideas to vern@txis.com. In the meantime, I have an article to prepare. See you next month! **NV**

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Happy Thanksgiving!

From All Of Us At Ramsey Electronics!



Tickle-Stick Shocker

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4 Tickle Stick Kit \$12.95



Super Snoop Amplifier

Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output drives any speaker for a great sound. Makes a great "big ear" microphone to listen to the "wildlife" both in the field and in the city! Runs on 6-15 VDC.

BN9 Super Snoop Amp Kit \$9.95



Dripping Faucet

Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound just like a drip into a bowl of water! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Drives any speaker for a cool sound. Runs on 4-9 VDC.

EDF1 Dripping Faucet Kit \$9.95



LED Blinky

Our #1 Mini-Kit for 35 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Used throughout the world as the first learning kit for students young and old! Great solder practice kit. Runs on 3-15 VDC.

BL1 LED Blinky Kit \$7.95



Cricket Sensor

Not only does it chirp just like a real cricket, it also senses temperature and changes the chirp accordingly. Can actually determine temp by chirps! Squishing under your feet voids warranty! Runs on 9VDC battery. Speaker included.

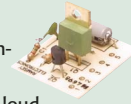
EC51 Cricket Sensor Kit \$24.95



Electronic Siren

Exactly duplicates the upward and downward wail of a police siren. Switch closure produces upward wail, releasing it makes it return downward. Produces a loud 5W output, and will drive any speaker! Horn speakers sound the best! Runs on 6-12 VDC.

SM3 Electronic Siren Kit \$7.95



Universal Timer

Build a time delay, keep something on for a preset time, provide clock pulses or provide an audio tone, all using the versatile 555 timer chip! Comes with circuit theory and a lots of application ideas and schematics to help you learn the 555 timer. Runs on 5-15 VDC.

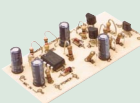
UT5 Universal Timer Kit \$9.95



Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

VS1 Voice Switch Kit \$9.95



Tone Encoder/Decoder

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Great for sub-audible "CTS" tone squelch encoders or decoders. Drives any low voltage load up to 100mA. Runs on 5-12 VDC.

TD1 Encoder/Decoder Kit \$9.95



RF Preamp

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 RF Preamp Kit \$19.95



Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Dries any low voltage load up to 100mA. Runs on 6-12 VDC.

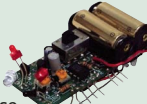
TS1 Touch Switch Kit \$9.95



Walking Electronic Bug

Built around a pair of subminiature cell phone motors, this bug wanders around looking for things to bump into! Sensors below his LED eyes sense proximity and make him turn away! Steer him with flashlights too! Runs on two "N" batteries.

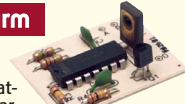
WEB1 Walking Bug Kit \$29.95



Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

MB1 Mad Blaster Warble Alarm Kit \$9.95



DTMF Encoder Decoder

Decodes standard Touch Tones from telephones, radio, or any audio source. Detects and decodes any single digit and provides a closure to ground up to 20mA. Great for remote tone control. Runs on 5VDC.

TT7 DTMF Encode/Decode Kit \$24.95



Cable Polarity Checker

Checks continuity AND polarity of a pair of wires! Simply connect the remote board to one end, and the tester to the other end and LED's show opens, shorts, and polarity! Even includes auto power off! Runs on a standard 9V battery.

MK132 Cable Polarity Checker \$7.95



Water Sensor Alarm

This little \$8 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump!). When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.

MK108 Water Sensor Alarm Kit \$7.95



RF Actuated Relay

Just what you need when adding a preamp or power amp in line with an antenna! Auto senses RF and closes an on-board DPDT relay that's good to UHF at 100W! Also great to protect expensive RF test equipment. Senses as low as 50mW! Runs on 10-15VDC.

RFS1 RF Actuated Relay Kit \$19.95



Light Actuated Switch

Tired of turning your lights off? This little kit auto senses light and automatically closes the on-board SPDT relay. Light sensitivity is adjustable and a delay circuit prevents recycling. Relay contacts are rated at 5A. Runs on 12-15VDC.

MK125 Light Actuated Switch Kit \$7.95



Power Saver Timer

Add time delay power-off to any of your projects or circuits! Momentary push button selects desired time delay (1H, 2H, 4H, 8H, 24H) and LED flashes faster as time approaches. On-board 10A relay. Runs on 120/240VAC.

K8075 Power Saver Timer Kit \$24.95



IR Remote Control Checker

Is your IR remote control working? Just point and shoot, and this kit will let you know! Confirms IR signal generation from any IR remote and displays proper receipt on the four LED display. Don't change the batteries, check the remote first! Runs on a standard 9V battery.

MK137 IR Remote Checker Kit \$6.95



Stereo Ear Super Amplifier

Ultra high gain amp boosts audio 50 times and it does it in stereo with its dual directional stereo microphones! Just plug in your standard earphone or headset and point towards the source. Great stereo separation besides! Runs on 3 AAA batteries.

MK136 Stereo Ear Amplifier Kit \$9.95



Steam Engine & Whistle

Simulates the sound of a vintage steam engine locomotive and whistle! Features variable engine speed and volume. Whistle blows at a touch of a button! Great for model train setups. Includes the speaker. Runs on a standard 9V battery.

MK134 Steam Engine & Whistle Kit \$10.95



SMT Multi-Color Blinky

The ultimate blinky kit! The 8-pin micro-controller drives a very special RGB LED in 16 million color combinations! Uses PWM methods to generate any color with the micro, with switchable speed selection. SMT construction with extra parts when you lose them! Runs on 9V battery.

SBRGB1 SMT Multi-Color Blinky Kit \$29.95



SMT High Intensity Blinky

The SMT revival of our classic BL1! Super bright SMT LED's alternately flash in a brilliant display. Subminiature construction makes it perfect for badges and displays. SMT construction with extra parts when you drop them! Includes two LR55 button cells.

BL2 SMT High Intensity Blinky Kit \$17.95



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- ✓ It's impossible to give you full specs on these products in a 1" space!
- ✓ A lot of our kits are also available "factory assembled and tested", if you don't want to build it!
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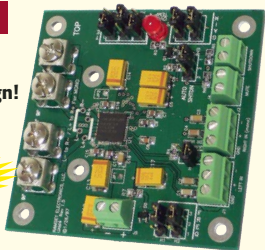
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- ✓ Super efficient Class D spread spectrum design!
- ✓ Built-in click and pop suppression!
- ✓ Selectable gain from +22dB to +36dB!
- ✓ Logic level mute and shutdown!
- ✓ Runs cool, no heat sink required!
- ✓ Built-in thermal protection!
- ✓ Runs on 10 to 18 VDC

New For 2008



40 Watts, 87% Efficient, No Heat, All On A 2½" Board!

The UAM4 is the big brother to the extremely popular UAM2. It uses the latest spread spectrum amplifier technology to bring you clear, crisp, high-power audio without any of the heat which is normally associated with such an amplifier. It's extremely clean Class D design produces two independent 20 watt outputs! This can also be bridged to an extremely efficient (87%) single channel (mono) 40 watt amplifier.

And at 40 watts, you're probably already wondering about the heatsink requirements to dissipate the heat, right? Stop wondering, there's no heat, so there is no heatsink required! And all that power is generated in a single SMT device the size of your thumbnail on a small 2½" square board!

The high impedance input is designed to use your choice of either a balanced line input or an unbalanced signal source using easy to connect Euro terminal blocks. Logic connections to ground are also provided to mute and/or shut down the amplifier. You can also enable the built-in over temperature signal to activate one of these controls automatically! Easy to use board jumpers offer selectable gain of +22dB, +25dB, +29.5dB or +36dB to match your input levels. Board jumpers also enable protection and shutdown options as well as stereo/mono/bridge mode. The amplifier also features built-in click and pop suppression to protect not only your ears and sanity, but your speakers and equipment!

Power input for maximum rated output is 18VDC at 2.64A. Input voltage can be reduced to a minimum of 10VDC while maintaining the same high efficiency operation with reduced output power. If you're looking for an incredible stand-alone stereo (or mono) amplifier to build into your equipment, vehicle, speakers, or application, the UAM4 is the latest and the greatest!

UAM4 Subminiature 40W Stereo Audio Amplifier Kit \$69.95

Laser Trip Sensor

- ✓ True Laser detects over 500 yards!
- ✓ Audible & visual alert!
- ✓ 5A external trigger relay

At last, a true laser beam alarm within the reach of the hobbyists! Comes complete with a small key-chain type high power laser pointer, laser detector, and PVC enclosure.

The unique break-away circuit board allows you to remotely locate the sensor from the detector board. Range is over 500 yards, and with the addition of simple mirrors, complete perimeter protection is a snap! The detector board includes both audible and visual indicators plus a built-in 5A relay provides closures for any alarm functions you need. Detector requires 9-18VDC or a standard 9V battery.

LTS1 Laser Trip Sensor Kit \$29.95

3-in-1 Multifunction Lab

- ✓ Digital multimeter!
- ✓ Regulated power supply!
- ✓ Temp controlled soldering station!
- ✓ RoHS lead-free compatible!

Take a close look! On your left is a multi-function 3½ digit digital multimeter. Its large backlit LCD display can be seen from anywhere on your bench while you're working. The DMM also features built-in transistor, diode, and continuity testing plus data hold and audible alarm.

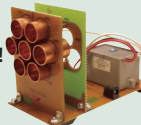
Next up, the regulated lab DC power supply. Switch selectable ranges of 3V, 4.5V, 6V, 7.5V, 9V, and 12V provide a continuous duty current of 1.5 amps with a 2 amp peak! Features both overload protection and overload indication.

To the right we have a high quality temperature regulated soldering station. The 24V low voltage iron features an isolated ceramic 48 watt temperature controlled element. Front panel control gives you variable tip temperature control from 150°C to 450°C and LED indication of power-on and heating-on. Runs on 120VAC.

LAB1U 3-in-1 Multifunction Lab \$119.95

Ion Generator

- ✓ Generate 7.5kV DC!
- ✓ Blast of fresh air without any moving parts!



Build this neat Ion generator and watch the 7 ion wind tubes generate an ion filled blast of fresh air! No fan blades, no motors, no noise, just swift-ly moving charged air!

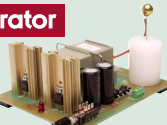
Designed to teach the principles of ion propulsion and how spacecraft use ions to accelerate through space, and at the same time providing a really neat ion air cleaner! Comprehensive theory learning information is included.

Generates 7.5kV DC negative at 400uA, and that's a LOT of ions! Runs on 12-15VDC at 500mA.

IG7 Ion Generator Kit \$64.95

Plasma Generator

- ✓ 2" sparks!
- ✓ Generates 25kV!
- ✓ Build your own plasma balls!



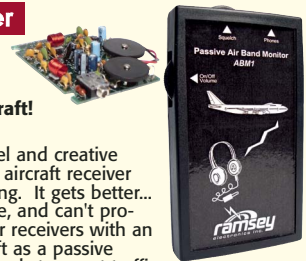
Generates 25kV at 20kHz from a solid state circuit! Produce stunning lighting displays, generate big sparks, and do a lot of experiments with this high voltage plasma generator!

Take a regular Decora style light bulb and create great looking plasma balls. Light fluorescent tubes without wires. Generate 2" sparks to a handheld screwdriver! While generating 25kV, it's low current is relatively safe. The PG13 runs on 16VAC for full output, or 5-24VDC to vary the output voltage. If you want to learn about plasma and high voltage, this is the kit for you!

PG13 Plasma Generator Kit \$64.95

Passive Aircraft Airband Receiver

- ✓ Monitors the entire 118-136 MHz aircraft band without tuning!
- ✓ Great for air shows!
- ✓ Passive design, can be used onboard aircraft!
- ✓ Patented circuit and design!



For decades we have been known for our novel and creative product designs. Well, check this one out! An aircraft receiver that receives all nearby traffic without any tuning. It gets better... there is no local oscillator so it doesn't produce, and can't produce, any interference associated with all other receivers with an LO. That means you can use it onboard aircraft as a passive device! And what will you hear? The closest and strongest traffic, mainly, the one you're sitting in! How unique is this? We have a patent on it, and that says it all!

This broadband radio monitors transmissions over the entire aircraft band of 118-136 MHz. The way it works is simple. Strongest man wins! The strongest signal within the pass band of the radio will be heard. Receiver sensitivity is less than 2uV for detectable audio. Headset cord is coupled as the antenna giving you great reception. Also includes a set of stereo ear buds. Runs on a standard 9V battery. Available thru-hole kit or SMT factory assembled & tested.

ABM1 Passive Aircraft Airband Receiver Kit \$89.95
ABM1WT Factory Assembled & Tested ABM1, SMT Version \$159.95

FM Stereo Transmitter

- ✓ PLL synthesized, drift free!
- ✓ Front panel digital control!
- ✓ Professional metal case
- ✓ Super audio quality



For decades we have been the leader in hobbyist AM & FM transmitters. The legacy continues with the FM30B! Rock stable PLL synthesized circuit keeps you dead-on frequency. A user friendly multi-mode front panel interface gives you full control of ALL operating parameters with a brilliant 2-line LCD display. EMI filtering and microstrip inductors reduce microphonics and noise normally associated with hobby transmitters. RF power output is continuously variable from 0-25mW.

Runs on 13.8-16VDC and includes a switching AC power supply. Get on the air today with your own FM30B! Visit www.ramseykits.com for complete details.

FM30B Synthesized FM Stereo Transmitter Kit \$199.95

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WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ **Parallel Transistors**
- ✓ **Thermocouple Multiplexer**
- ✓ **Oscilloscope Isolation**

WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:

Q&A@nutsvolts.com

PARALLEL TRANSISTORS

Q In regards to the schematic in Figure 4 on page 29 of the July '07 issue, I have some MOSFET related questions. The IRL2703 has an absolute maximum drain current rating of 24A (I assume with proper heatsinking). Let's say I wanted to power a 24VDC motor that draws 30A. My question is can two IRL2703s be paralleled to handle the current requirement of the motor? And if so, how many parallel MOSFETs could the LM5100 be capable of driving? Or, could the drains and sources of the MOSFETs be paralleled and each gate be driven by its own LM5100?

The reason I ask is that I am starting to experiment with DC motors (mini electric vehicle research) and I am looking for a simple H-bridge motor controller circuit with minimal drive components that could be adjusted for different motor current by simply paralleling the power transistors.

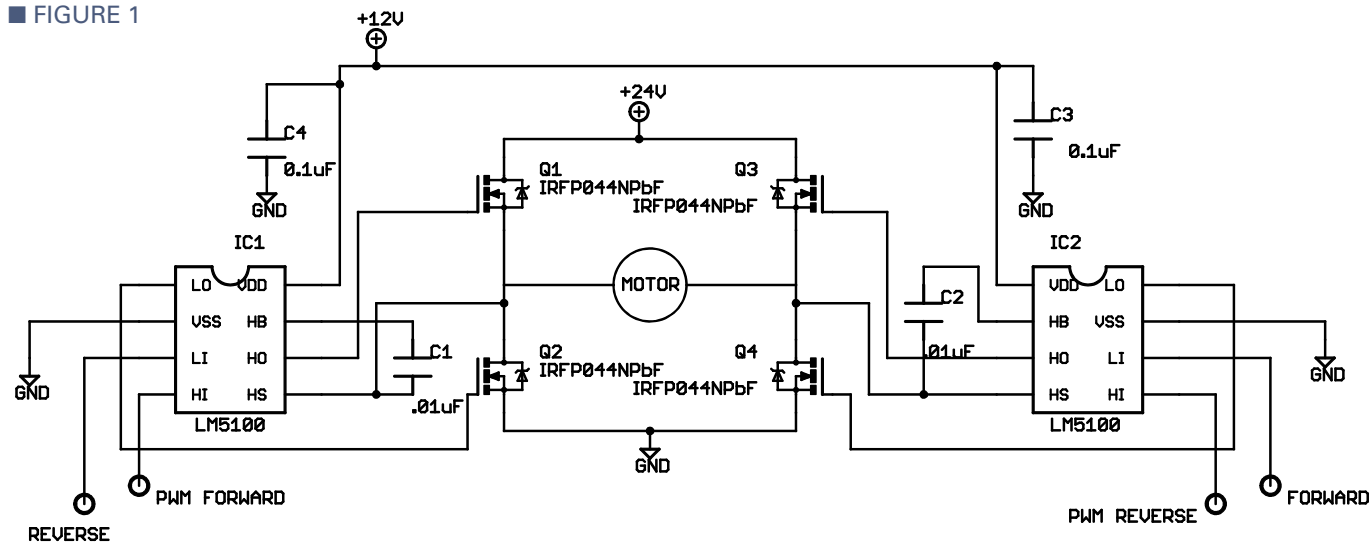
— Daniel Byrant

A I once tried paralleling power MOSFETs and gained a large number of blown transistors, so I don't recommend it. Perhaps if you put a series resistor in each source to equalize the currents, it could work, but that is not efficient. It's much better to use one transistor rated for the maximum current that you expect. You can get IGBT transistors rated to 100s of amps. Mechanical switches are more efficient than transistors, so you might think about using relays to reverse the motor and for dynamic braking.

The LM5100 can drive any number of parallel transistors; it is just a question of drive frequency. The LM5100 can drive 5,000 pF at 20 kHz; that is a mighty big MOSFET. The IRFP044NPbF is rated at 55V and 53A; its input capacitance is typically 1,500 pF, so the LM5100 could drive it to 100 kHz. You only need the frequency to be above the audible range for a motor driver.

I should point out that Figure 4 on page 29 of the July issue is a specialized H-bridge in that only one side is switching. That brings up a problem that I had not noticed: the LM5100 only works in a switching circuit; it does not work in a static situation, as in the left side of the schematic. Figure

■ FIGURE 1



5 on that page shows how I should have done it.

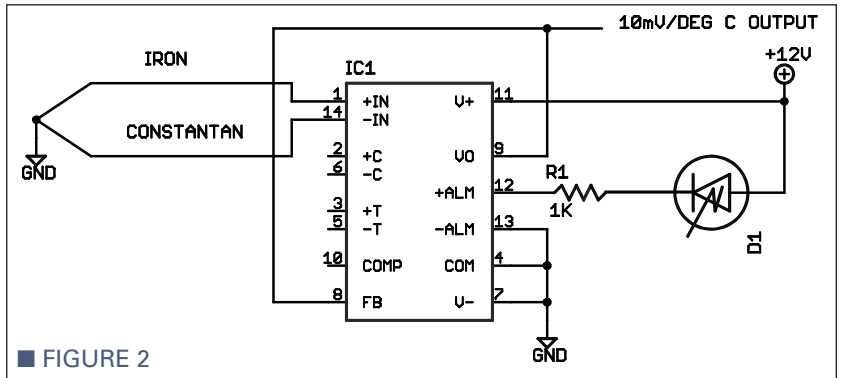
Speed control requires feedback. For a vehicle, your eyeballs and the speedometer are part of that feedback. If you want cruise control, however, a tachometer is required.

In Figure 1, if Q1 is PWM, driving the motor forward, then Q4 is turned on continuously and Q2 and Q3 are off. When you want the motor to stop, Q2 and Q4 are turned on and Q1 and Q3 are off. This puts a short across the motor, slowing it down quickly. To reverse the motor, Q3 is PWM and Q2 is on. It takes time to turn Q1 off, so there must be a delay before Q2 is turned on. You could use a microprocessor to handle the details, but with a 555 timer and some switches, a simpler (for me) circuit could be designed.

You will need some safety features. For example, it should not be possible to switch from forward to reverse when the accelerator is floored. Putting a short on the motor for dynamic braking could throw the vehicle out of control, so that needs to be addressed. I recommend using only regeneration for braking and use the mechanical brakes for stopping. Dynamic braking won't stop the vehicle any sooner and you have to have mechanical brakes anyway.

THERMOCOUPLE MULTIPLEXER

Q I need a circuit to cycle four pairs of thermocouple signals for a four cylinder air-cooled engine (CHT and EGT) at a cycle rate of 30 to 40 seconds for the four. As each cylinder cycles on, I need it to also indicate the cylinder number (1-2-3-4) on a seven segment LED. A selective hold switch would also be helpful for extended



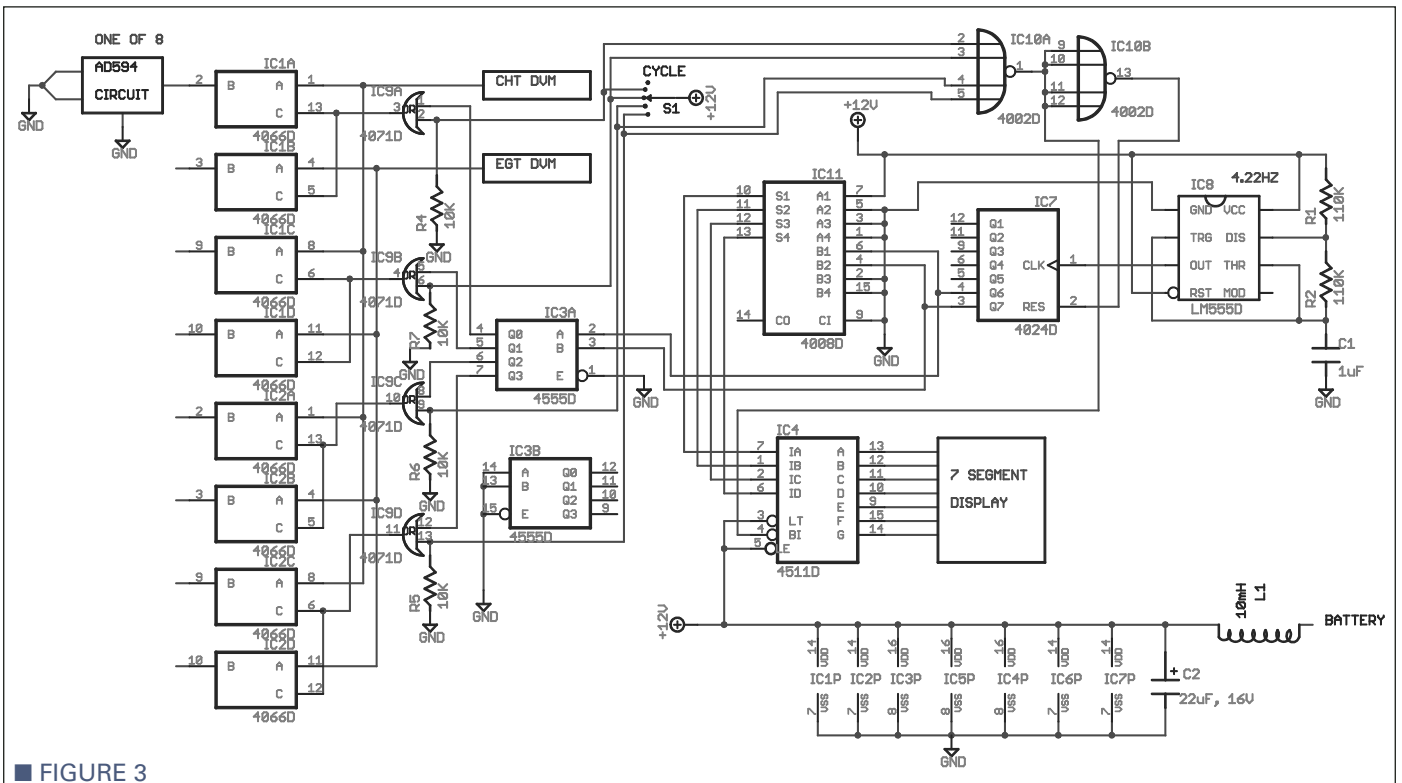
■ FIGURE 2

viewing of any particular cylinder. The power source is 12 volts.

— A. F. Schwedler

A A microprocessor would be handy for this project, but I am a newbie and can gin up a logic circuit faster than I could figure out and debug a program. In researching for this answer, I learned that CHT stands for cylinder head temperature and EGT stands for exhaust gas temperature. I recall a similar question where I used a Fluke model 80TK thermocouple module which outputs the temperature directly in millivolts. The Analog Devices AD594 has built-in cold junction compensation and outputs 10 millivolts per degree C. It will be less expensive and since you will have to have a printed circuit board anyway. I will go with the AD594, which comes in two flavors: the A version is trimmed to three degrees accuracy; the C version is trimmed to one degree accuracy. The AD594 is compensated for type J thermocouples, good to 750 degrees C max (1,382 degrees F).

Figure 2 is the detail schematic for the AD594. You will

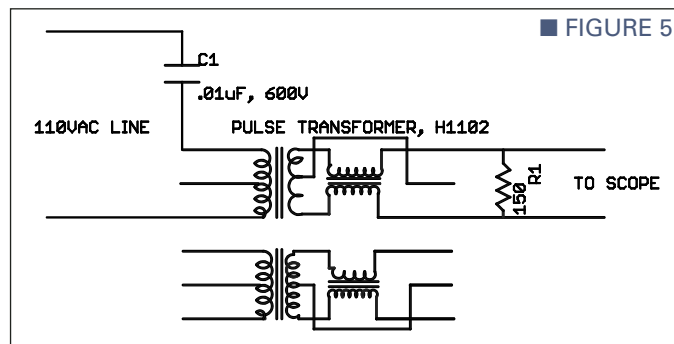


■ FIGURE 3



Part	Description	Part No.
<i>All parts are from Allied Electronics (www.alliedelec.com) unless otherwise noted.</i>		
AD594AQ	Thermocouple IC	630-1070
AD594CQ	Thermocouple IC	630-0664
IC1, IC2	Quad analog switch	568-0645
IC3	One of four decoder	568-1205
IC4	BCD to seven segment	735-1349
IC7	Seven stage ripple count	735-0907
IC8	555 timer	288-0666
IC9	Quad two input OR	735-1004
IC10	Dual four input NOR	735-1065
C1	1 μ F, 50 V	852-0899
DISPLAY	Single digit	263-0537
R1, R2	110K, 1/8W	895-1161
R4,5,6,7	10K, 1/8W	895-0355
S1	One pole, adj positions	10WA144/Mouser (www.mouser.com)

■ FIGURE 4. Thermocouple multiplexer parts list.



■ FIGURE 5

need eight of them; one for each thermocouple. It is important that the thermocouple is grounded, but if grounding the junction is not convenient, you can put a 10K resistor from the negative input to ground.

In Figure 3, the AD594 outputs are routed to a digital voltmeter (DVM) using a pair of quad analog switches (4066). The analog switches are controlled by a 4555 one-of-4 decoder. I originally considered feeding the two bits of the 4555 input to a seven segment decoder but that would count 0-1-2-3 and I want it to count 1-2-3-4. I put the 4002 four bit adder in cascade with the BCD to seven segment decoder to provide the 1-2-3-4 count. I never used an adder before — I hope it works!

The switch, S1, allows continuous viewing of one cylin-

MAILBAG

Dear Russell,

Congrats on a very innovative and flexible charger (July '07, page 33). Do you know if the voltage sag at full charge is also present with alkaline cells? I recharge AA and 9V batteries frequently and get quite a bit of extended life. I plan to build one of these chargers for my lab.

Also, congrats on being a PICBASIC PRO user. Except for floating point math, I have not found anything that I wanted to do that I could not accomplish with PBPro. It's a real genius piece of work.

In your code for the charger, I believe that you need to initialize the value of Oldvolt on the first pass through to zero volts or some low value just to make sure that some flakey value is not stored at runtime and you inadvertently shut down on the first comparison with Volt. It may happen automatically but I like to be in control. Also, I plan to add a few sequential measurements with averaging just to make sure that I don't get bit by a one time noise glitch.

Thanks for picking up the reins from Mr. Byers — he left some big shoes to fill. I never met him, but I will always remember him.

— Bill Jorden
Tucson, AZ

Response: I don't know about alkaline cells, my knowledge is limited

to what I have read on the Internet. It is possible that the cell will gas and have reduced terminal voltage. If you try it, let me know if it works.

Thanks for the feedback on the code. Your points are well taken.

Dear Russell,

I'm very new to electronics and trying to educate myself. What is the purpose of Figure 14 on page 34 of the July '07 issue? Can IC 12F675 be programmed or something? Also, what is A/D input (last paragraph)? Does someone make a PCB or entire kit for the charger? What does the reset switch look like?

— Bill Higgins

Response: Figure 14 is the PICBASIC PRO program for the microprocessor, PIC12F675. You can get more information from www.melabs.com. You can also download the datasheet for the PIC12F675 at www.excelpoint.com.cn/documents/pic12f675.pdf. There is a great deal of information in the datasheet; it will take some time to digest it all. There is a forum that will be helpful at www.picbasic.co.uk/forum/.

The PIC12F675 has a built-in analog-to-digital (A/D) converter you can read up on that is in the datasheet. There is no kit; I did build a breadboard to verify that it works. There is no reset

switch. I suppose I could have had one because there are unused pins, but I did not think it was necessary.

Dear Russell,

The figure you have for the mixer output in the August '07 issue does not seem to be correct to me. The two signals are indeed added. The description of a mixer often does state that the output contains sum and difference frequencies. However, the equations for a mixer are of a multiplicative relationship. Please see the ARRL Handbook for a picture of what a mixer output should be. The figure you have shown could easily be the output of an operational amplifier "adding" two sine wave signals.

— Jlcldc via email

Response: You are correct that the operation of a mixer involves multiplication; the multiplication occurs in the non-linearity of the amplifier. The math is beyond me; I just know that it works. If both signals are small, no mixer action occurs and there is no sum or difference at the output. But if one signal is large and the other is small, the small signal is run up and down the non-linearity of the amplifier producing a multiplication effect. Note that in Figure 2 (August, page 25) the period of the waveform is 0.1 μ S = 10 MHz, the difference frequency, not the addition of the two inputs.

Mailbag continued ...

Dear Russell,

I have a wee problem with the circuit you show in Figure 6 of the August issue. Analysis shows that it would send a continuous stream of pulses to the servo at a rate that may lock the servo.

In an R/C system using pulse position modulation, one sends a frame of pulses at approx. 20 ms intervals. On the transmit side, each pulse triggers the next pulse, etc. In an eight channel system if all pulses are 2 ms, the total time for the pulses is 16 ms. The remaining blank space is used by the receiver to determine the start of the frame.

Hence, for Anonymous to control the throttle, he would need the attached circuit. The astable produces pulses at 20 ms intervals; the frame and the monostable produces a pulse between 1 and 2 ms per frame. I don't think a

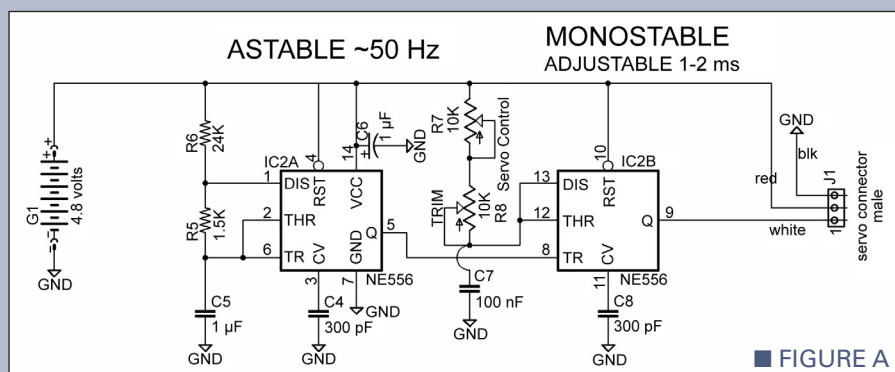


FIGURE A

switchover is necessary if the engine is a gas engine. It is easier to set up the controls in such a way that a 1 or 0.9 ms pulse effectively shuts off the fuel flow, cutting the engine.

For a more complete explanation of PPM, see N&V January '06, Auxiliary control unit.

I enjoy reading your column, keep it going.

— Paul J. Weijer

Response: Thanks for the feedback. The R/C system is more complex than I knew. Thanks also for your circuit which is Figure A.

der. In the zero position, the display cycles normally but when any cylinder is selected, the 4002 dual four bit NOR resets the counter, stopping the cycling and blanking the display.

The 4024 counter divides by 128. The last two bits are used to provide the four count, so dividing the 30 seconds needed to cycle through the four cylinders, the period for the 555 oscillator is 0.234 sec or 4.22 Hz. The resistors, R1 and R2, don't have to be equal and you can increase them to extend the viewing time.

The parts list for the thermocouple multiplexer is provided in Figure 4.

OSCILLOSCOPE ISOLATION

I would like to use a Tektronix oscilloscope, Model T922, to view the following signals:

- 1) Telephone line when my PC is utilizing it.
- 2) 110 VAC power line to view X-10 control signals.

Both require some isolation, but I am not sure how to do this.

— Anonymous

1) The telephone company takes a dim view of anyone connecting unapproved equipment to their lines, so you will need an approved interface. Commercial units are expensive, so I recommend getting an old telephone — one that has a separate base and handset. Unscrew the earpiece and connect your scope across the speaker. The waveform may be improved by replacing the speaker with a resistor (10 ohms?). Before you do this, disconnect your scope from ground. I use a three prong to two prong adapter that is available in most hardware stores.

2) The X-10 signals are high frequency (120 kHz), so a capacitor will separate the 60 Hz and the X-10 signals. A

transformer will provide the safety isolation. The transformer should be a pulse type which will further attenuate the 60 Hz (see Figure 5). I looked for an ordinary 1:1, 100 ohm transformer but this 10/100 base-T unit was as close as I could find. It is a dual; you only need to use half of it. Mouser part number is 673-H1102. **NV**

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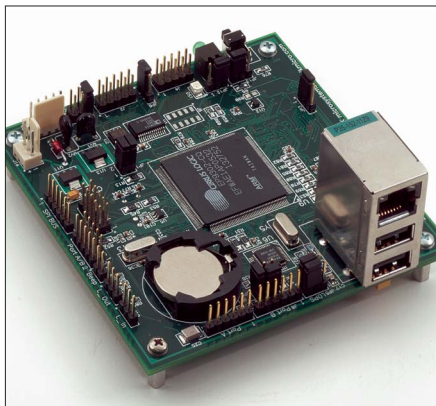
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EZX10RF has a built-in power line interface and its programming and control are done through the power line or programming and details can be done without the use of external controllers or software. The unit is supported by home automation software packages such as an open source provided by Simplehomenet.

During setup, the EZX10RF receiver will simply identify a unique X10 address and associates it with



INSTEON "group" numbers from 1-20. Although the number of storable X10 identifiers is limited to 20, multiple devices can be set up with a software setup utility on a PC to have the same INSTEON group number, thus enabling multiple X10 devices to act on the same INSTEON units.

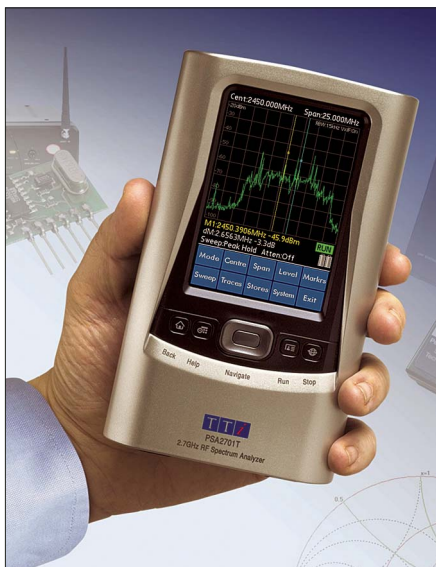
Unlike other whole house X10 transceivers with whip antennas, the EZX10RF has an antenna built on the left side of the enclosure that can be oriented to point vertically regardless of the transceiver position. For convenience, a pass through outlet is provided.

President Alfredo Choperena says, "Our homes should be viewed and treated as harmonious integrated systems, and not as collections of disconnected appliances and sub-systems; that is our goal. With the launch of the EZX10RF, we are closer to making this possible."

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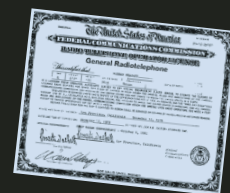
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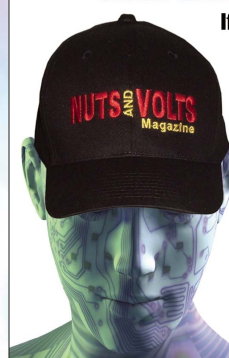


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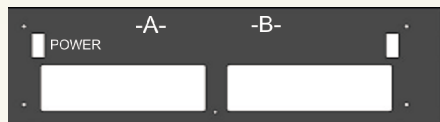
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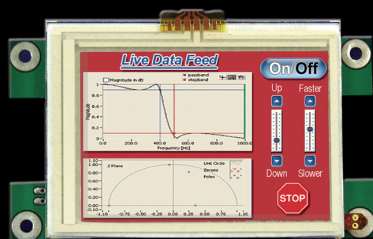
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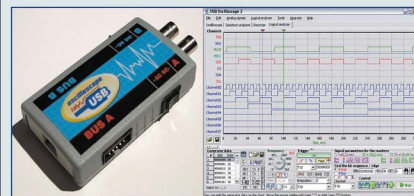
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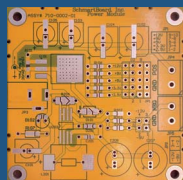
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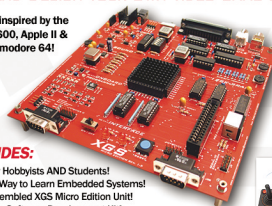


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■ LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

- Beginner Level
- Intermediate Level
- Advanced Level
- Professional Level

**Everyone has heard
the saying**

**"necessity is the
mother of invention."**

**Well, that is what gave
birth to this project.**

BUILD A REMOTE BATTERY BANK VOLTAGE MONITOR

I was approached by Bruce Harcey, KR4LI, of Mission Aviation Fellowship (MAF) in Shell Ecuador after he learned that I had been involved in the design, construction, and installation of remote data acquisition and control using telemetry here in Havre, MT for the local wireless Internet service provider when I was volunteering at MAF in Redlands, CA in the avionics shop. Dave (the Internet service provider) and I had installed a

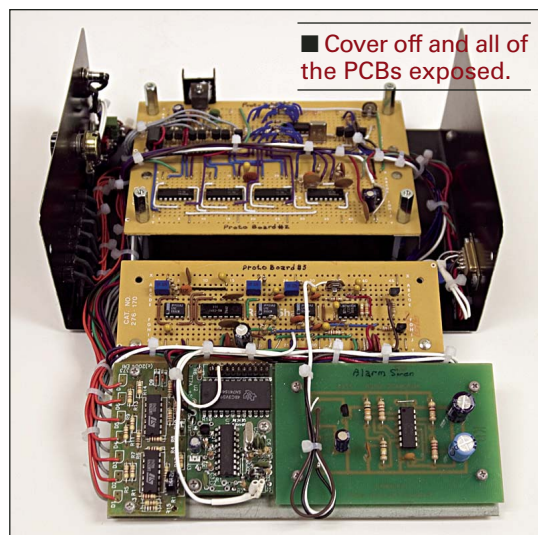
couple of remote hilltop facilities and needed to be able to monitor and control these sites. So, we implemented the data acquisition and control systems.

Bruce is an Avionics Specialist in the headquarters of the MAF's Ecuador Program. He has many responsibilities among which are the two-way radio systems. He wanted to know if I could help him come up with a way to monitor the battery bank voltage on their newly

■ Front panel of the completed unit.



■ Cover off and all of the PCBs exposed.



installed repeaters and solar power systems. They had just installed new Kenwood 570 repeaters and Connect Systems, Inc., model TP-154 shared repeater tone panels on two mountain tops to replace older equipment that was starting to show signs of its age.

After many email chats concerning his likes and dislikes related to data acquisition and control, and the complexity of the need, it all came down to simply monitoring the battery bank voltage and being able to get that voltage value at any time — day or night. We then listed several objectives which included: a small physical size; a small current consumption; simple to operate; easy to maintain; constructed from easy-to-find electronics components; built for the steamy jungle environment; lightning resistant; easy to interface and well documented with an easy to understand manual.

The voltage monitor presented here is an electronic device that is designed to be interfaced to a repeater controller at a solar powered alternative energy repeater site. When it is interrogated, it will key the repeater transmitter, and it will transmit Dual Tone Multi Frequency (DTMF) touch tones that represent the voltage level of the battery bank voltage to the control radio station. It does this by monitoring the battery bank voltage and then converting the voltage level to a DTMF touch tone digit; there is one touch tone of seven possible touch tones for each of seven voltage levels.

The control radio has a DTMF touch tone decoder and a numerical digit converter interfaced to the receiver. It converts the DTMF touch tone to a number from 1 to 7 that represents a voltage level and displays it on a screen. Interrogation is accomplished by encoding a DTMF touch tone "A" control tone on the control radio's transmitter when transmitting.

An alarm siren feature has been incorporated in the voltage monitor and will automatically send a wailing siren alert tone when the battery bank voltage has reached either a lower or

CONSTRUCTION DECISIONS AND TIPS

When I started this project, I did a lot of research in magazines and on the Internet and I found many sources for remote-controlled data acquisition and control systems. They all seemed to be overkill for our needs at Shell, though. I found microprocessor-controlled repeaters with time, temperature, supply voltage, etc., capabilities along with voice synthesizers to announce all this information. However, MAF had already installed the new shared repeater tone panels. So, the answer was to design and build our own dedicated single function voltage monitor system. I didn't use a microcontroller for the project because I don't have a strong background in programming, even though I have done machine level programming in the past.

After giving this subject a lot of thought, I came up with the DTMF touch tone idea using mostly kits that could be interfaced together to reduce the amount of design and construction time. The initial idea was to be able to use a DTMF touch tone control digit to interrogate the voltage monitoring device located on the mountain top for the battery voltage and then have it send back DTMF touch tone numbers that would represent voltage levels. However, the project grew to include an alarm siren that would automatically signal upper and lower voltage limits and an audio power amplifier to aid in troubleshooting.

I had been eyeing the 12 volt DC monitor kit by Rainbow Kits (model VM2-12) because I thought it would be a good fit for the voltage monitor portion of the system. I also knew that Ramsey made a reliable DTMF touch tone decoder kit (model TT7). In previous research, I found several for the Gibson Tech Ed., Inc., kit model 9924 siren because it was the easiest to control and would warble. I ended up making an DTMF touch tone encoder on a small proto construction board with a low pass

filter and a low power audio power amplifier to drive a Model 27 speaker kit by Kitsrus for acoustically coupling to the radio system control stations at the hangar.

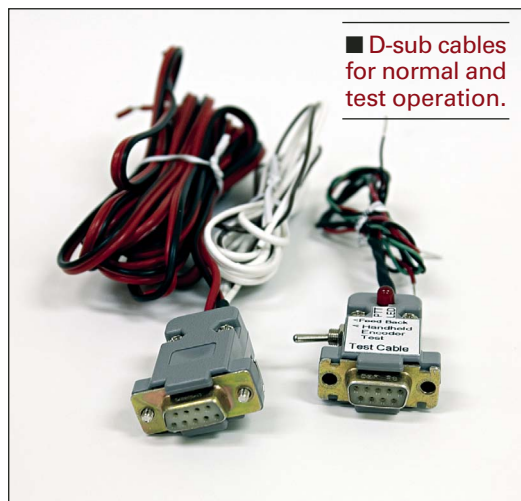
The first thing I had to do was to convert the output of the seven voltage comparators of the Rainbow kit into one logic "high" at a time, rather than a series of high states (this is the action of an LED based on a signal strength "S" meter. The greater the voltage that is measured, the more LEDs would be on.)

I used Electronics Workbench (a circuit simulation program) to help me design the logic circuits that monitor the outputs of the voltage comparators. These, in turn, drive the siren.

I always build circuits on breadboards so I don't get a bunch of surprises before I solder the parts onto the proto construction boards. I always leave my assembled breadboard intact, so I can go back to it to recheck and compare the operation of the two circuits. I also make it a practice to check each individual circuit for proper operation as I complete it so I don't have to troubleshoot the whole circuit at once.

I also used a computer software program called DraftCAD to help with the documentation. The CAD software is handy because the circuits can be resized and moved easily around on a page. I also used the CAD program for the layout of the front panel and the holes that needed to be punched or drilled in the enclosure.

When soldering ICs onto a PCB, it is my practice to remove the soldering iron upward for an inch or so before starting to solder the next pin. This way, any solder strings that might form will be straight up and will not extend to the next pin. On DIP ICs, I solder pins on alternate sides of the DIP package. These techniques will help prevent solder bridges.



■ D-sub cables for normal and test operation.

an upper voltage limit.

The final design produced a monitor that is housed in an enclosure with the dimensions of 5-7/8" W x 8-1/8" L x 3" H that includes two stacked layers of printed circuit boards (PCBs). The average standby current consumption is just less than 170 ma. To reduce current consumption, I used high resistance voltage dividers on the input circuits of the flip flops and on the trigger input pins of the timers.

The best feature that conserved current was the ability to shut off the LEDs when they were not needed (when the voltage monitor was in normal operation at the repeater site). The LEDs are only used during installation, proof of performance, maintenance, repair, and calibration. Another current saving step would involve the reduction of the volume

control during normal operation at the repeater site.

The system is very easy to operate as it only requires the transmission of a control tone in order to cause the voltage monitor to reply with the voltage level data. The layout design of the electronics circuits is made to fold out to allow easy access to either side of the PCBs for easy maintenance. Popular bipolar transistors, such as the 2N3904, 2N3906, and PN2222, were selected for the project, as well as 7400 series TTL logic, an LM555 timer, and an LM741 op-amp.

In order to reduce the effects of corrosion on the voltage monitor, we reduced the socket count and soldered the transistors and IC into the PCB. There is only one DB-9 connector in the back of the enclosure. We decided to use a D-type connector because there are two cables for the voltage monitor: one cable for normal operation and the other cable for testing and maintenance.

In order to reduce the effects of lightning on the voltage monitor, a machine screw is placed on the rear of the enclosure to connect it to the grounding system. We also incorporated a metal oxide varistor (MOV) on the power supply wires at the D-connector pins. A further consideration was not to design in any CMOS transistors and ICs that are more susceptible to static discharges.

Interfacing the voltage monitor is very simple and only requires three connections to the repeater controller: two connections for audio input and output and the other for Push-to-Talk (PTT).

Operating Instructions

Turn on the POWER and LEDS switches. Turn the volume control to mid position. You should see some of the LEDs light up on the lower right of the front panel. The LEDs indicates the voltage level of the battery bank. The greater the bank voltage, the greater the number of LEDs that will be lit, going left to right.

Transmit the DTMF touch tone control tone "A" from the control radio station by keying the transmitter with the PTT switch and holding the handheld DTMF touch tone encoder speaker output to the microphone. Press the red pushbutton switch on the side of the encoder enclosure. A DTMF touch tone should be heard from its speaker (the tone is acoustically coupled to the microphone).

The voltage monitor will key the repeater transmitter, indicated by the PTT LED on its upper left corner. The voltage monitor will feed the repeater transmitter with a DTMF touch tone that represents the voltage level of the battery bank. This DTMF touch tone will be received by the control station receiver and will be decoded by the DTMF decoder and a number will be

displayed. (Please refer to Table 2 for the corresponding voltage levels.)

When it's verified the system is operating properly, shut off the LEDs with the appropriate switch (this helps conserve power).

In order to disable the alarm siren and keep it from occurring every 10 minutes, simply perform the above procedure again. This action resets the alarm siren drive circuit. Keep in mind the volt-

Voltage Step Name	Voltage Step Actual Name	LED Indicator Color
9 Volts	9.9 Volts	Red
10 Volts	10.73 Volts	Yellow
11 Volts	11.7 Volts	Green
12 Volts	12.4 Volts	Green
13 Volts	13.3 Volts	Green
14 Volts	14.1 Volts	Yellow
15 Volts	15 Volts	Red

■ TABLE 1. This chart shows the relationship between the names of each voltage step and the actual voltage value for each step after the Voltage Monitor has been properly calibrated. Proper calibration is just at the point where the 15 volt red LED turns on. Therefore, this step has a voltage level of 15 volts to 16 volts.

Voltage Step Name	Voltage Step Actual Name	LED Indicator Color
#1	9.9V-10.7V	Red
#2	10.7V-11.7V	Yellow
#3	11.7V-12.4V	Green
#4	12.4V-13.3V	Green
#5	13.3V-14.1V	Green
#6	14.1V-15V	Yellow
#7	15V-16V	Red

■ TABLE 2. This chart shows the relationship between the names of each voltage steps to the actual voltage value for each step. Proper calibration is when LED #7 just lights at 15 volts when the voltage is ascending. Therefore, this step has voltage level of 15 to 16 volts.

age monitor will send back the battery bank voltage level again from repeating the function.

Theory of Operation

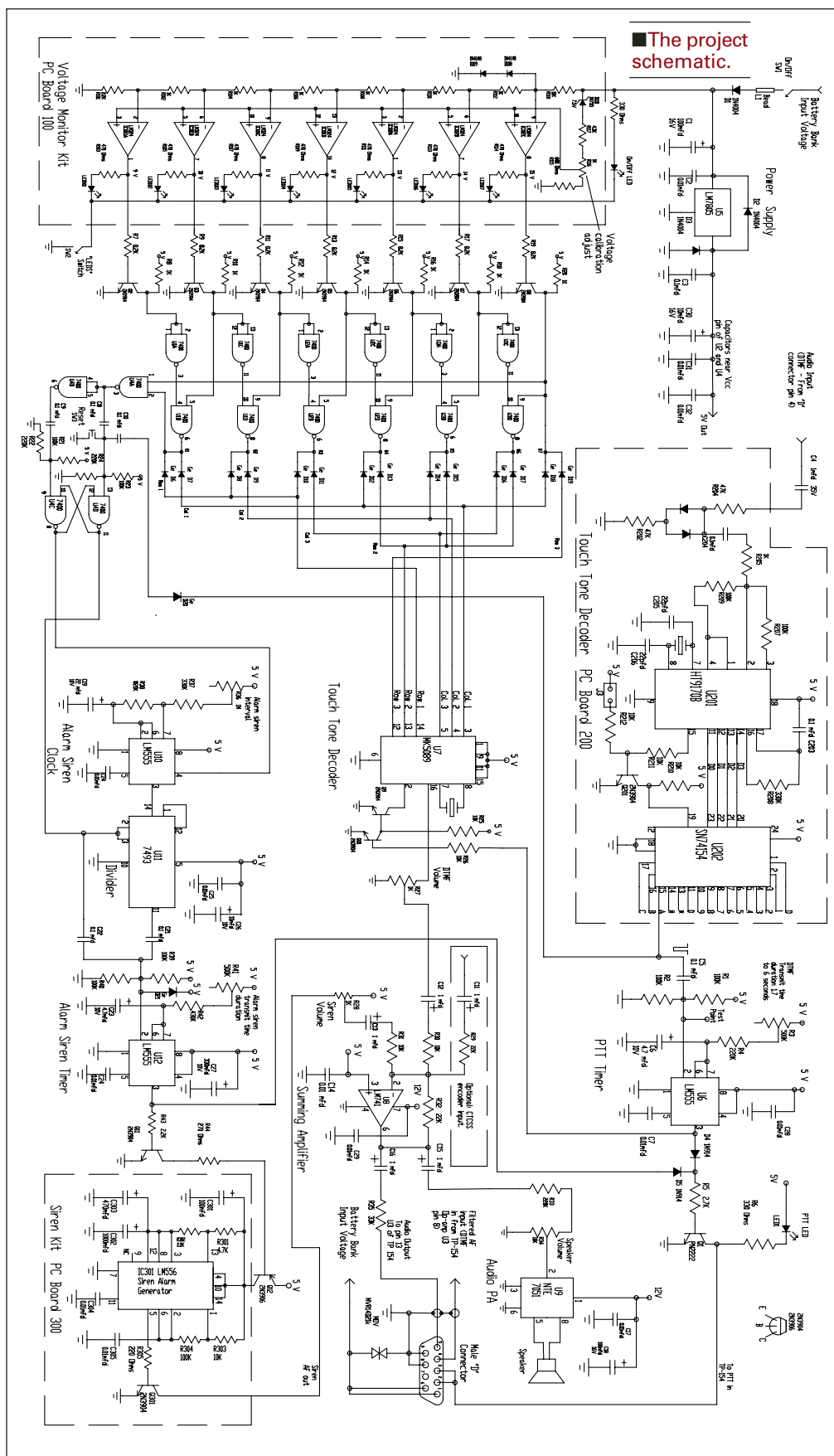
The repeater receiver audio from the Connect Systems repeater controller is brought into the voltage monitor at the D-connector, pin 4, on the rear of the monitor where it is fed to the DTMF tone decoder PCB #200, at capacitor C4. When a DTMF touch tone control tone "A" is decoded, the voltage on pin 18 of the 22 pin header pin plug on the PCB #200 will go to a logic low state. The negative-going leading edge triggers the PTT timer U1 and the output of the timer will go to a logic high state, which is adjustable from 1.7 to 6.9 seconds.

The output of this PTT timer saturates the transmitter keying transistor Q1 through the OR-ing diode D4 which keys the repeater transmitter. Also, this output saturates the transistor switch Q10 which, in turn, shuts off Q9 and enables the DTMF encoder U7 to generate the correct touch tones that represent the voltage level of the battery bank.

The DTMF touch tone audio from U7 is adjusted by the DTMF amplitude adjustment control R27 for proper transmitter modulation and then fed into the summing amplifier U8. The DTMF audio is amplified 2.2 times and fed to the D-connector, pin 5 on the back of the monitor. The DTMF output voltage level is from 0 to 5 Vp-p. This output is fed to the repeater controller to modulate the repeater transmitter.

The output of the summing amplifier is also fed to a low power audio frequency PA, U9, which drives the speaker on the bottom of the monitor. The volume control for this speaker is on the front.

The project schematic.





PARTS LIST

ITEM	VALUE	QTY
Main Circuit:		
<input type="checkbox"/> R44	270 ohms	1
<input type="checkbox"/> R6	330 ohms	1
<input type="checkbox"/> R7-20	1K	14
<input type="checkbox"/> R43	2.2K	1
<input type="checkbox"/> R5	2.7K	1
<input type="checkbox"/> R25, 26, 30, 31	10K	4
<input type="checkbox"/> R29, 32	22K	1
<input type="checkbox"/> R35	33K	1
<input type="checkbox"/> R1, 2, 21, 23, 39, 40	100K	4
<input type="checkbox"/> R4	200K	1
<input type="checkbox"/> R22, 24, 33	220K	3
<input type="checkbox"/> R37	330K	1
<input type="checkbox"/> R42	430K	1
<input type="checkbox"/> R38	820K	1
<input type="checkbox"/> R27, 28	1K POT	2
<input type="checkbox"/> R34	10K POT	1
<input type="checkbox"/> R3, 41	500K POT	2
<input type="checkbox"/> R36	1M POT	1
<input type="checkbox"/> C2, 7, 14, 17, 24, 25, 29, 31, 32	0.01 μ F	9
<input type="checkbox"/> C3, 5, 8, 9, 10, 21, 22, 28,	0.1 μ F	8
<input type="checkbox"/> C4, 11, 12, 13, 15, 16,	1 μ F	6
<input type="checkbox"/> C6, 23	4.7 μ F 10V	2
<input type="checkbox"/> C26	10 μ F 10V	1
<input type="checkbox"/> C30	10 μ F 16V	1
<input type="checkbox"/> C19	22 μ F 10V	1
<input type="checkbox"/> C1, 18	100 μ F 16V	2
<input type="checkbox"/> C27	330 μ F 16V	1
<input type="checkbox"/> D1, 2, 3	1N4004	3
<input type="checkbox"/> D4, 5	1N914	2
<input type="checkbox"/> D6-21	GE	16
<input type="checkbox"/> L1	BEAD	1
<input type="checkbox"/> MOV		1
<input type="checkbox"/> SW1, 2, 3	SPST	3
<input type="checkbox"/> Q1	PN2222	1
<input type="checkbox"/> Q2-11	2N3904	9
<input type="checkbox"/> Q12	2N3906	1
<input type="checkbox"/> U6, 10, 12	LM555	3
<input type="checkbox"/> U8	LM741	1
<input type="checkbox"/> U1-4	LM7400	4
<input type="checkbox"/> U5	LM7805	1
<input type="checkbox"/> U7	MK5089	1
<input type="checkbox"/> U9	NTE7051 1	1
<input type="checkbox"/> U11	LM7493	1
<input type="checkbox"/> SPEAKER		1
<input type="checkbox"/> MALE "D" PLUG		1
<input type="checkbox"/> FEMALE "D" PLUGS		2
<input type="checkbox"/> METAL CASE		1
<input type="checkbox"/> FEET		4
<input type="checkbox"/> PRINTED CIRCUIT PROTO BOARD		3

continued ...

The battery bank voltage is monitored by the circuit found on PCB #100 which is made from seven voltage comparators, IC101 and IC102. The battery bank voltage is fed to the voltage monitor circuit on pins 1 and 6. A resistive voltage divider made of R101, R102, R104, R106, R108, R110, R112, and R118 provides the input voltages for the comparators.

A low battery bank voltage will cause the first comparator, IC101A to have a high voltage output which will cause LED101 to light; this is step voltage #1. All the remaining comparators will not have adequate input voltage to cause their outputs to go high; therefore the remaining LEDs will not be lit.

As the battery bank voltage increases, the second comparator IC101B output will go high which will cause LED102 to light; this is step voltage #2. Now two LEDs are lit. This action continues as the battery bank voltage increases until all the outputs of the voltage comparators are high and all the LEDs are lit.

The output of the voltage comparators are fed to transistor logic state inverters, Q2-Q8. The transistor circuits have two functions. First, they convert the state of the logic and secondly, then convert the battery bank operating voltage of 9-16 volts to a five volt level to drive the five volt logic circuits.

The logic circuits U1-U3 convert the output logic states that monitor the battery bank voltage on the PCB #100 to one logic state low of seven logic

state outputs which is fed to the diode matrix circuit. The low logic state simulates a pressed pushbutton switch on a touch tone keypad.

When the battery bank voltage is low, the output of IC1B has a low voltage state. All the other diode matrix drivers, IC1D, IC2B, IC2D, IC3B, and IC3D, are in a high logic state. When the battery bank voltage increases to the next level for LED102 to light, the low logic state is passed to the output of IC1D, and causes the output of IC1B to rise to a high logic state. This logic low state is passed on to each diode matrix driver as the battery bank voltage increases. When the battery bank voltage increases to the highest level, the diode matrix circuit is driven from the collector of Q8.

The diode matrix circuit is made up of germanium diodes, D6-D19. Each logic circuit's output will pull one row pin and one column pin on the DTMF touch tone encoder U7 to a logic low state.

The alarm siren circuit starts with a two-input NAND gate, U4A. Its two inputs are fed from the output of U1B pin 6 and the collector of Q8 and is negative logic. Therefore, the operation of the NAND gate is doing an OR function. When either red LED is lit, the input to this NAND gate will cause a high logic state at its output pin 3. This high state is passed along to the input of a NAND gate, U4B, which is wired as an inverter; its output falls to a low logic state.

It is the leading edge of this falling logic state that passes through the 0.1 μ F capacitor, C9, to a set/reset flip-flop and sets its output to a high logic state on NAND gate, U4D, output pin 8 and a low logic state on NAND gate, U4C, output pin 11. These two logic states drive the alarm siren control circuit.

When the battery bank voltage level increases or decreases from the red LED lit condition, the two inputs to the NAND gate U4A rise to a high logic state and the output of this gate falls to a low logic state. The leading edge of this falling logic state is coupled through the 0.1 μ F capacitor, C8, to the flip-flop and resets it so the

Remote Battery Bank Voltage Monitor

logic state on NAND gate, U4D, output pin 8 falls to a low logic state and the output of the NAND gate U4C, output pin 11 rises to a high logic state. These logic states disable the alarm siren control circuit. The RS flip-flop can be reset by pressing the SW3 RESET pushbutton switch on the front of the voltage monitor (this also disables the alarm siren circuit).

The high logic state from the output of NAND gate, U4C, pin 8 is applied to the reset input pin of the alarm siren clock U10, pin 4 and causes the timer to start to function in the astable operating mode; that is, it functions as a clock. The output from this clock is fed to the input of a divide-by-16 divider U11. The output of the clock is divided by 16 at the output, D, pin 11, and cycles the logic state every 10 minutes. Pins 2 and 3 of the divider U11 are the "zero" set pins.

When they are in a high logic state, the output of the divider is 00H. Therefore, each time the alarm siren circuit is reset, the divider is reset to 00H, so the alarm siren occurs every 10 minutes. When the RS flip-flop changes state so the NAND gate, U4D, output pin 11 falls to a low logic state, the count begins at 00H and counts towards FFH.

In addition, the leading edge of this falling logic state is also coupled through the 0.1 μ F capacitor, C22, to trigger the alarm siren timer U12, and the output, pin 3, rises to a high logic state. The alarm siren timer U12 can be triggered on by the falling leading edge logic state from the D output of the divider at pin 11 every 10 minutes. It is coupled to the alarm siren timer through the 0.1 μ F capacitor, C21. The output of the alarm siren timer U12 saturates Q1 through the OR-ing diode D5 which keys the repeater transmitter. Also, the output of this timer turns on the transistor switch Q11-Q12 and enables the alarm siren.

The output of the siren feeds the summing op-amp U8 through the siren volume control, R28. The sound of the alarm siren will be heard from the speaker in the bottom of the

voltage monitor and the alarm siren signal voltage is also fed to the repeater transmitter.

The power supply consists of voltage regulator U5 which regulates the battery bank voltage to five volts to power the circuits of the voltage monitor. On the input and output leads of the voltage regulator IC, there are filter capacitors to filter out any RF and AC voltage components and prevent the voltage regulator from oscillating.

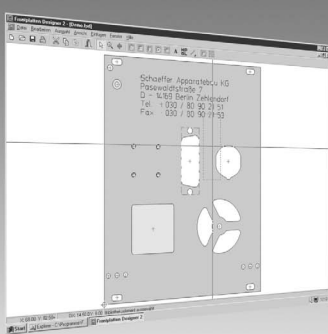
Diodes D2-D3 are used to prevent the voltage regulator from being destroyed from a sudden drop in the battery bank voltage. Attached to the D-connector on the battery bank input leads is a MOV for lightning protection. Following the on/off switch is a bead inductor, L1, and a reverse polarity protection diode, D1 for increased voltage protection, an erratic battery bank voltage, and any RF and AC voltage components. **NV**

Parts List continued ...

ITEM	VALUE	QTY
Voltage Monitor Kit, PC Board 100:		
□ R103, 105, 107, 109, 111, 113, 114	470 ohms	7
□ R115	680 ohms	1
□ R101, 104, 106, 108, 110, 112	1K	6
□ R102	2.2K	1
□ R117	4.3K	1
□ R118	10K	1
□ R116	1K POT	1
□ IC1, 2	LM324	2
□ D108, 109	1N4146	2
□ D110	1N765	1
□ D101-107	LED	7
□ PRINTED CIRCUIT BOARD		1
Touch Tone Decoder PC Board 200:		
□ R205	1K	1
□ R210, 211, 212	10K	3
□ R202, 204	47K	2
□ R207, 209	100K	2
□ R208	330K	1
□ C205, 206	22 pF	2
□ C203, 204	0.1 μ F	2
□ Q201	2N3904	1
□ U201	HT9170B	1
□ U202	SN74154	1
□ PRINTED CIRCUIT BOARD		1
Siren Kit PC Board 300:		
□ R305	220 ohms	1
□ R302	2.2K	1
□ R301	4.7K	1
□ R303	10K	1
□ R304	100K	1
□ C304, 305	0.01 μ F	2
□ C301	100 μ F	1
□ C303	470 μ F	1
□ C302	1,000 μ F	1
□ Q301	2N3904	1
□ IC301	LM555	1

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I have seen several simple alarm circuits in *Nuts & Volts* through the years,

but this one is a little different in that it connects directly to popular lines of Genie garage door openers.

While I use it with a model IS550, it should work with many Genie models (all Intellicode screw drive models from 1997-present) that share a common sequencer board #31184R. This should include models CM8700, CM8600, CM7600, PRO95, Series II, ISL950A, IS550, GCL, H6000A, H4000A, and IS. If in doubt, check that the opener switch connects the #1 and #2 screw terminals to open and close the door, and that the safety beam signal is on terminal #3 and is a 3 ms pulse train that is interrupted when the IR beam is broken.

GARAGE ALARM

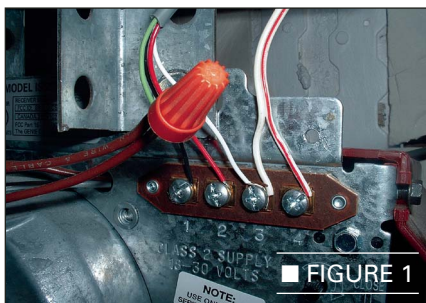


FIGURE 1

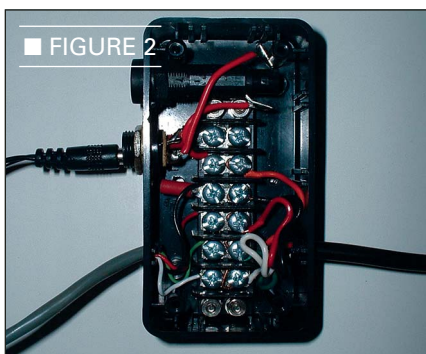


FIGURE 2

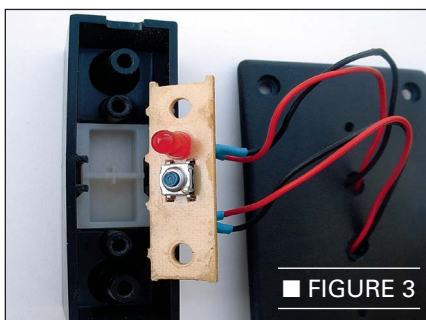


FIGURE 3

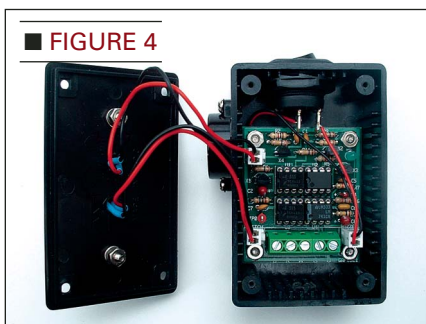


FIGURE 4

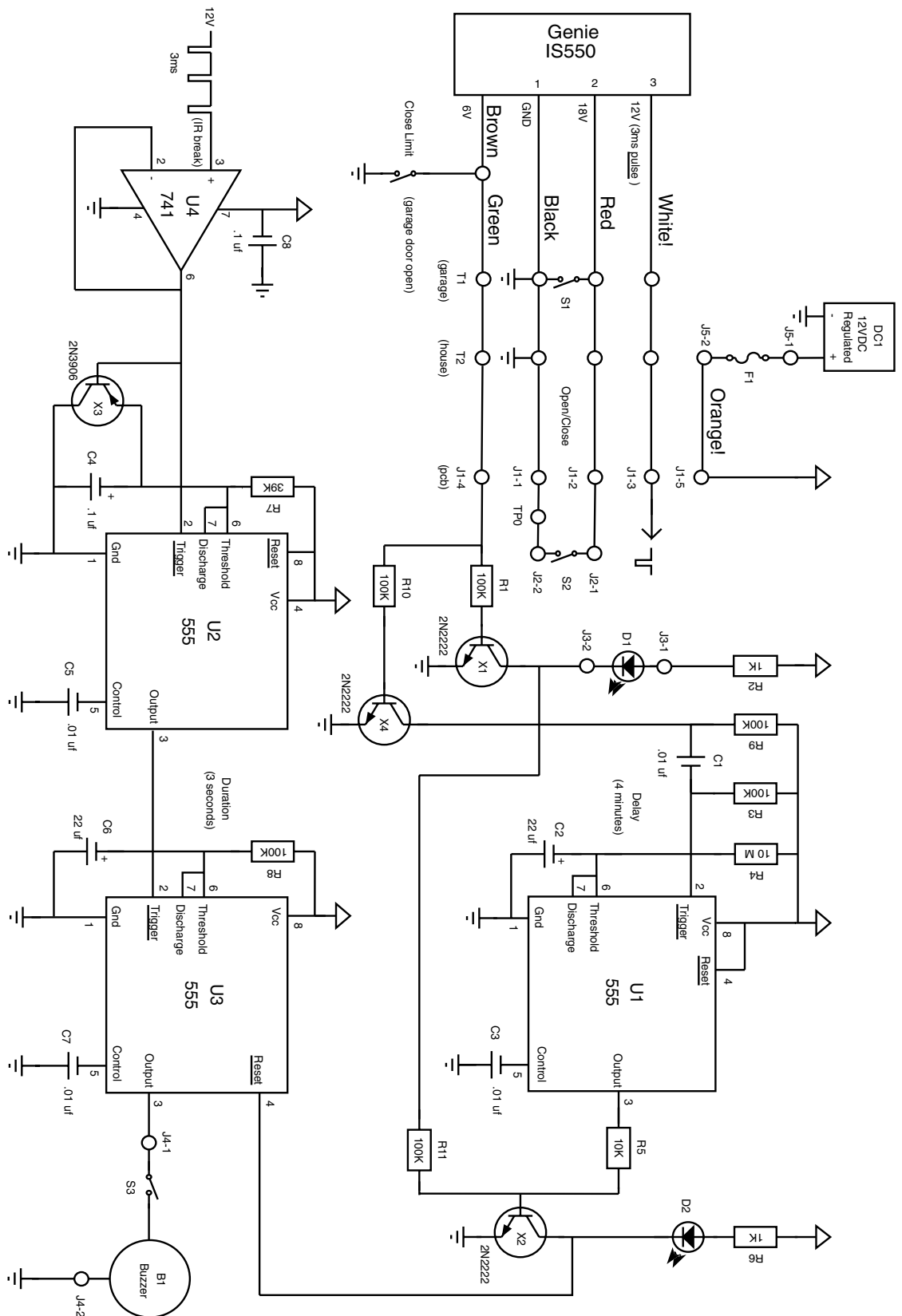
I cannot see my garage from my house, so I wanted the opener switch to light when the door was open and have an audible alarm if anyone entered the garage. The switch LED is detected from the opener's close limit switch, and the alarm is triggered from the Genie's safety IR beam. While it is easy enough to step over the safety beam, I felt the common nature of these devices was enough to detect a casual intruder or a child entering the garage. I don't think I could get a car by one.

The connection is a four conductor wire from the opener (Figure 1) to a junction box (Figure 2) near an AC outlet where the 12 VDC is introduced. Three wires connect directly to the Genie's screw terminals; the fourth must be spliced into the wire from the close limit switch. The rest of the wire run is five conductors to the alarm.

I used a sprinkler type of solid conductor wire from Home Depot. I placed my junction box inside the house, but it could be in the garage or eliminated entirely if the 12 VDC can reach the garage opener. In this case, just run five conductors the whole way.

Part of my decision to use a junction box was that I wanted the power supply fused during prototyping without having to use the space inside the alarm itself. The LED is mounted in the opener switch (Figure 3).

Opening the garage door turns on transistor X1, lighting LED D1, and triggering U1 to provide an alarm delay for normal garage usage.



Garage Alarm
V2.1 01-20-07

PARTS LIST

Item	Description	Manufacturer/Part #	Distributor/Part #
□ R1, R3, R8-R11	100K 1/4W		
□ R2, R6	1K 1/4W		
□ R4	10M 1/4W		
□ R5	10K 1/4W		
□ R7	39K 1/4W		
□ C1, C3, C5, C7	01 µF ceramic		
□ C2, C6	22 µF tantalum		
□ C4	.1 µF tantalum		
□ C8	.1 µF ceramic		
□ D1	LED, T1 3/4 size		
□ D2	LED, T1 size		
□ X1, X2, X4	NPN transistor	Fairchild/PN2222	RadioShack/276-1604
□ X3	PNP transistor	Motorola/2N3906	RadioShack/276-1604
□ U1-U3	Timer	Fairchild/LM555	RadioShack/276-1723
□ U4	Op-amp	National/LM741	RadioShack/276-007
□ B1	12V piezo buzzer		RadioShack/273-059
□ S1, S2	SPST mom. switch	Genie/GWB34690-R	Home Depot
□ S3	SPST rocker switch		RadioShack/275-693
□ J1	5 pos PCB block	Altech/AKZ250/5	Allied/502-0459
□ J2, J3, J4	2 pin header	Molex/22-23-2021	Jameco/232266CG
	2 pin female	Molex/22-01-3027	Jameco/234798CG
□ J5	2.1 mm DC jack	ValuePro/DPJ-021A	Jameco/151589CG
□ TP0	PCB test point	Keystone/5005	
□ T1T2	4 terminal block	Cinch/4-140	Jameco/230990CG
□ F1	.5A fuse		RadioShack/270-1018
□ FH1	Fuse holder		RadioShack 270-739
□ DC1	12VDC transformer	ReliaPro/DDU120050	Jameco/162996CG
□ Case1	3.125 x 2.0 x .875	ValuePro/H2855	Jameco/18921CB
□ Case2	4.875 x 2.5 x 1.5	ValuePro/H2853	Jameco/18913CB
□ PCB	Circuit Board	Advanced Circuits	(file) GAPCB21
□ Screws	4-40 w/nuts/washers/pan/round heads		

After about four minutes, the output of U1 (inverted through X2) goes high, enabling U3 to sound an alarm. If the safety IR beam is broken, the Genie's missing output pulses are buffered by

U4 and detected by U2 to trigger the alarm for about three seconds.

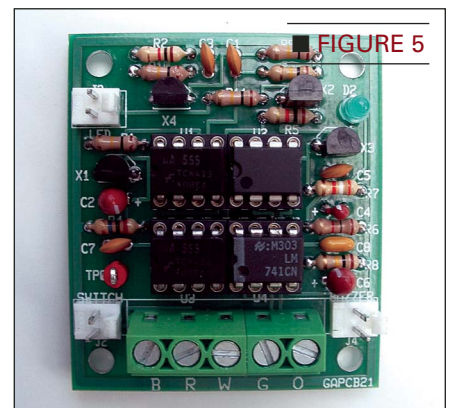
In my original design, the alarm sounded after the garage had been left open for a few minutes. This

pretty much drove me crazy. Version 2 triggered from the IR beam but left the alarm active at all times except for the initial delay; I figured that nobody could break the beam with the door closed. I found that the alarm would occasionally sound (usually in the middle of the night), sending me stumbling to see if the door was open. I don't know if this was from transient missing pulses or maybe a spider in the garage, but it was very annoying. This latest design configures X2 as a NOR gate so that the alarm is only active with the garage door open.

LED D2 is for troubleshooting. It is inside the case, and hopefully you will never see it (you can substitute a jumper if you wish). D2 lights when the alarm is disabled, either because the door is closed or during the delay period. With power applied, either D1, D2, or both should always be lit.

The mechanical construction is compact for aesthetic reasons (Figure 4), the circuit board is 1.75" x 2.00" (Figure 5) and the layout is available on the *Nuts & Volts* website at www.nutsvolts.com with all files necessary for construction contained in the file GAPBC21.zip. All of the components are widely available. I have also handwired this board using a RadioShack #276-159B prototype circuit board, but it is very tedious.

For the most important feature, there is an alarm kill switch on the top of the unit for those times when you actually want to work in the garage without annoying everyone in the house! **NV**



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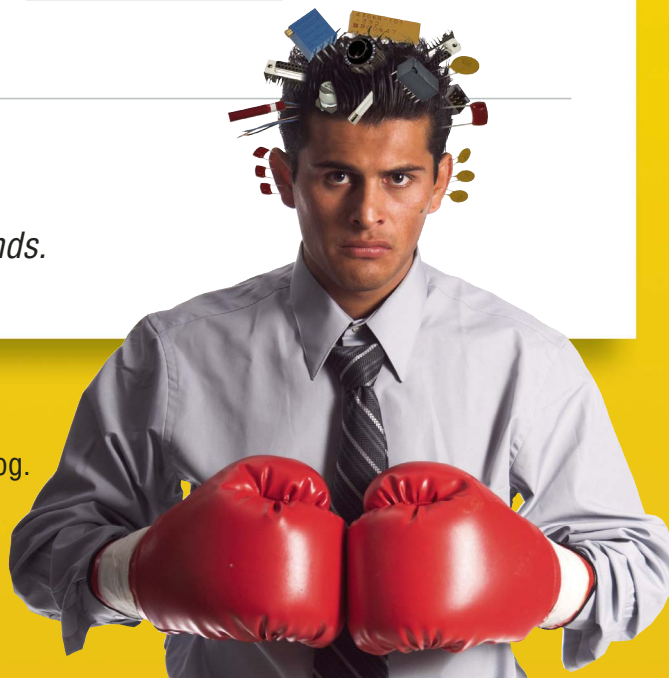
Jameco®	Digi-Key®	Mouser®	Newark®
AMP	AMP	AMP	AMP
Astec Power	Astec Power	Astec Power	Astec Power
Augat	AVX	AVX	AVX
AVX	Bourns	Bourns	Bourns
Bourns	Cherry	Cherry	Cherry
Cherry	Corcom	Condor Power	Corcom
Condor Power	CTS	Corcom	Elco Connector
Corcom	Elco Connector	Elco Connector	Grayhill
CTS	Fox Electronics	Fox Electronics	Int'l Rectifier
Elco Connector	Grayhill	Int'l Rectifier	Kemet
Fox Electronics	Int'l Rectifier	Kemet	Molex
Grayhill	Kemet	Molex	Osram
Int'l Rectifier	Molex	Panasonic	Panasonic
Kemet	Osram	Potter & Brumfield	Potter & Brumfield
Molex	Panasonic	Teledyne Relays	Vishay
Osram	Potter & Brumfield	Vishay	Wakefield
Panasonic	Power-One	Wakefield	
Potter & Brumfield	Vishay		
Power-One	Wakefield		
Teledyne Relays			
Vishay			
Wakefield			



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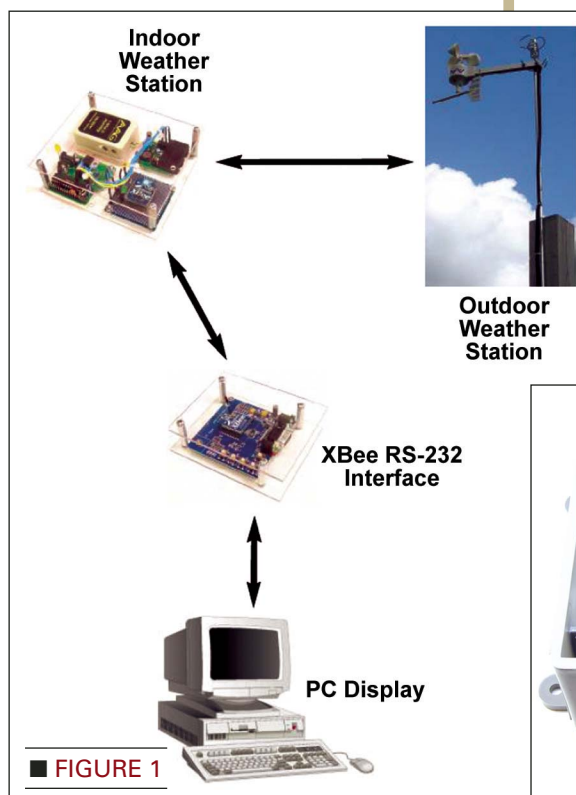
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In this installment
of the wireless
weather station,

I am going to show
you how to build
the outdoor
weather satellite.

Once assembled, we
will run some tests
with our indoor and PC
interface satellites, as
shown in the network
diagram in Figure 1.



CONTROL YOUR WORLD

Build a Wireless Weather System: Part 3

You should have the Maxstream mesh network firmware installed in each of the XBee modules you plan on using in your wireless network as outlined in Part 1 and 2 of this project. The indoor weather satellite needs to be assembled and tested, as the outdoor weather satellite will not function properly without it.

Building the Outdoor Weather Satellite

The purpose of the outdoor weather satellite is to collect data from your outdoor sensors. Since it is located outside, we need to make sure it is protected. To do this, we are going to mount the electronics in a weather-proof housing, like the one shown in Figure 2. I introduced you to this sensor back in March when we looked at the 1Wire environmental sensors. If you are already using one of these enclosures, you will need to purchase one more

since we need all the space inside for the components used to create our outdoor weather satellite.

To build this satellite, we will be using a DiosPro 28 chip and Carrier 1 board, XBee module and 3.3V interface kit, and a 5V regulator board. All these items will be attached to a piece of plastic and connected with SchmartBoard jumpers, also shown in Figure 2.

As we build this satellite, you can refer to Schematic 1 for detailed connection information.

- **STEP 1:** You will need one piece of acrylic (Figure 3). The acrylic should be cut to 4-1/8" x 2-3/4". Make sure you dry fit to the inside of your enclosure before you start mounting components.

- **STEP 2:** You need to assemble a Dios Carrier 1 board according to the included instructions, with the exception of the two 16-pin headers. For this project, you need to install the headers on the top of the board as shown in Figure 4.

- **STEP 3:** There are a couple of different ways to create a 5V interface to the 3.3V XBee module. The best way for this satellite is to use the Kronos Robotics 5V-3.3V kit and a SparkFun breakout board. This will create a very compact interface as shown in Figure 5.

You can find a detailed application note for this construction at www.kronosrobotics.com/Projects/MaxStreamInterface4.shtml.

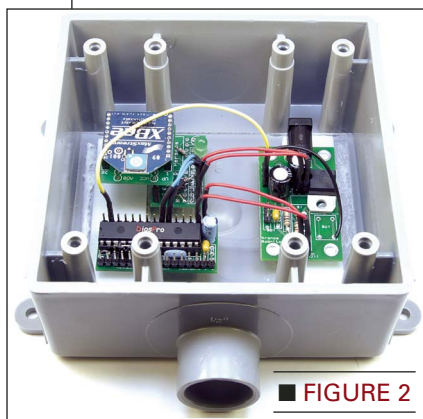
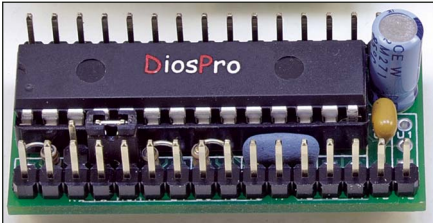


FIGURE 2

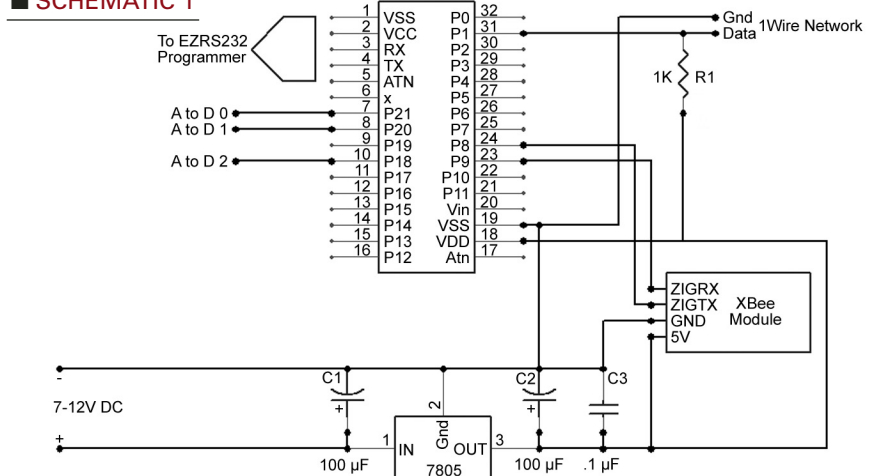


■ FIGURE 3



■ FIGURE 4

■ SCHEMATIC 1



• **STEP 4:** Assemble the Kronos Robotics five volt regulator board according to the included instructions (see Figure 6).

Referring to Schematic 1, the 1Wire network has a 1K resistor holding the data lead to +5V. We will make a few modifications to the regulator board to incorporate this resistor. First, place an additional jumper in the S1 position as shown in Figure 7. This ties the two outside pins on J8 together.

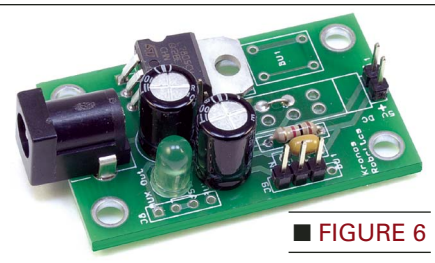
Next, connect a 1K resistor between this new jumper and the onboard resistor as shown in Figure 8. This pulls both the J8 outside pins to +5V with the resistor.

Install a four-pin header into the J8 connector as shown in Figure 9.

The last step is to connect a jumper between the BU1 lead and the third pin on the J8 header as shown in Figure 10. I used a small piece of heat shrink to cover the header. As an option, you can install a single pin header in BU1 and use a SchmartBoard jumper.

• **STEP 5:** Now attach the three completed modules to the 2-3/4" x 4-1/8" acrylic as shown in Figure 11. I recommend two layers of double stick foam tape.

• **STEP 6:** Now it is time to connect the power leads. Connect the + and - leads on the center header of the regulator to the + and - leads on the XBee module as shown in Figure 12. The outside lead on the XBee module is nega-



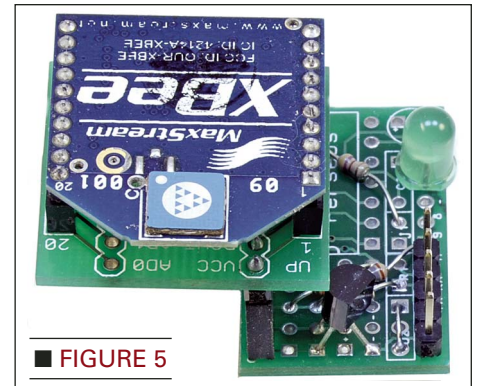
■ FIGURE 6

tive and the lead next to it is positive.

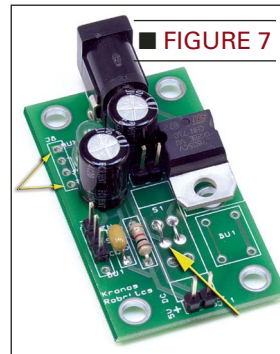
Connect the + and - leads from the end header on the regulator to the + and - leads on the Dios Carrier 1 module, also shown in Figure 12.

• **STEP 7:** Connect the "TX To Microcontroller" lead on the XBee module to the Dios Carrier 1 port 8. Connect the "RX From Microcontroller" lead on the Xbee module to the Dios Carrier 1 port 9. Both connections are shown in Figure 13. If you are not clear on the connections, refer to the XBee application note mentioned previously for a description of each pin.

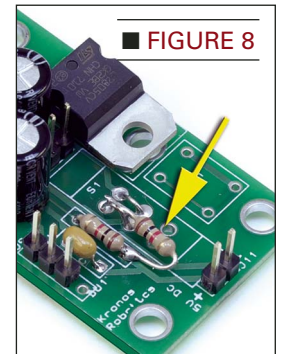
• **STEP 8:** The last jumper is connected between the last pin on the regulator J8 header, and port 1 on the Dios Carrier 1 as shown in Figure 14.



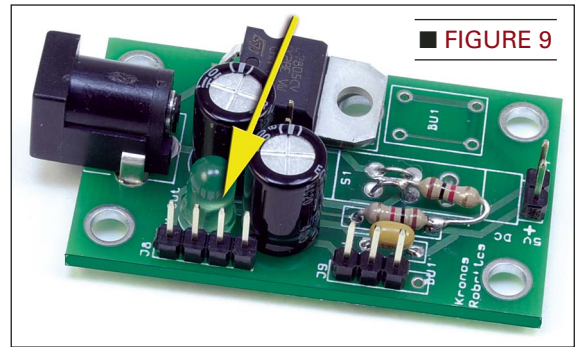
■ FIGURE 5



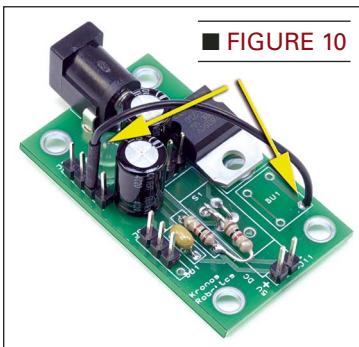
■ FIGURE 7



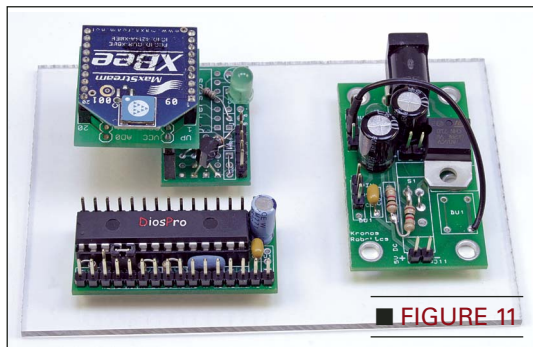
■ FIGURE 8



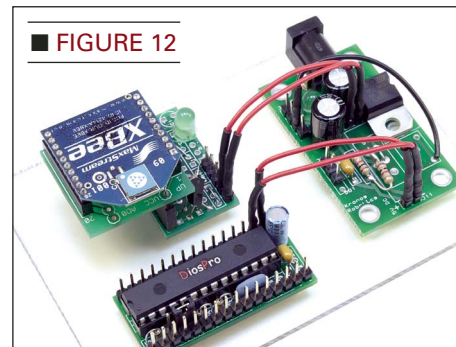
■ FIGURE 9



■ FIGURE 10



■ FIGURE 11



■ FIGURE 12

Testing the Indoor Satellite

You will need to use an AC adapter that supplies between seven and 12 volts DC to test the satellite. When you apply power to the 5V regulator, the LED on the regulator should light up. If it does not or is very dim, then you have a bad power connection somewhere. Disconnect the power immediately.

In order to program the DiosPro chip, you need an RS-232 adapter to connect the chip to your PC. These are available from the Kronos Robotics website for under \$10. The EZRS232 interface comes in kit form with a five-pin male header. In order to connect the EZRS232 to our Carrier 1, we need to create a small adapter by connecting two five-pin female headers together as shown in Figure 15.

As an option, you may forgo the

male header and attach a five-pin female header in its place as shown in Figure 16. This is the preferred method of programming the Dios Carrier 1 when the headers are on the top of the board.

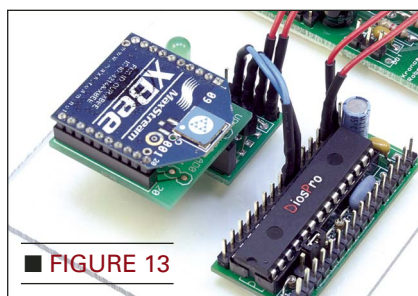
If you want to program the DiosPro chip once it is installed in the enclosure, you will need to make a small connector like the one shown in Figure 17. Make sure you use colored wire so that the pins mate up on both connectors. The colored wires also make it easier to connect the proper pins on the EZRS232 to the correct pins on the Dios Carrier 1. Once your outdoor weather satellite is mounted on your weather pole, you will have to use a laptop if you want to reprogram the DiosPro chip. Another option would be to use some sort of hook and loop to attach the satellite module to the enclosure. This way, you can remove the module whenever you wish.

The EZRS232 interface board is connected to the carrier by slipping the female header over the programming leads. These are the first five leads on the right side of the carrier as shown in Figure 18. You can now connect the PC to the outdoor satellite and apply power via the coax connector on the regulator.

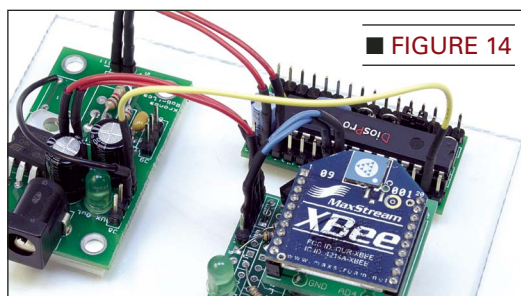
If you have not already done so, download and install the free Dios Compiler from the Kronos Robotics website. You can find a copy at www.kronosrobotics.com/downloads/DiosSetup.exe.

The DiosPro ships with a test program installed on the chip. When power is applied and the chip is connected to your PC, a test message will display in the debug terminal. This indicates that the chip is getting power.

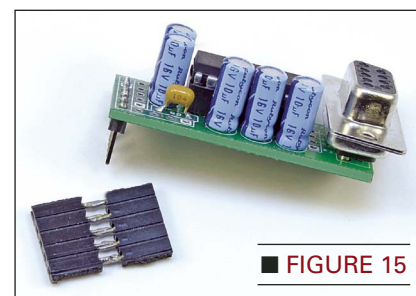
Load the code shown in Program 1 into the compiler and hit the program button. The compiler should compile



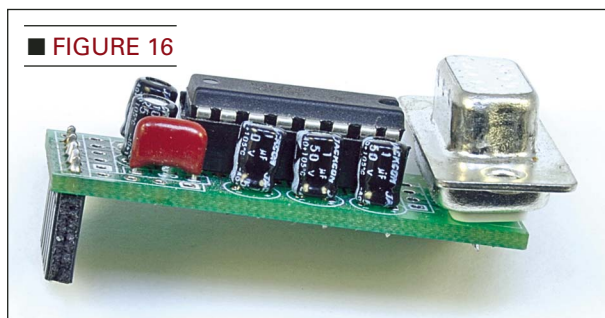
■ FIGURE 13



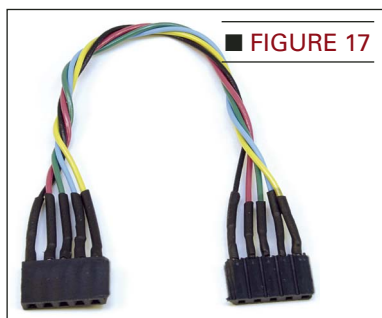
■ FIGURE 14



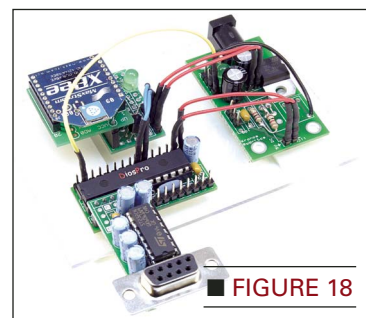
■ FIGURE 15



■ FIGURE 16



■ FIGURE 17



■ FIGURE 18

the program, then upload the code to your DiosPro chip. Once complete, a temperature of 99.9 will be displayed on the debug terminal. It will also be transmitted out over the network.

In order for the network to get configured properly when you apply power to the various satellites, the coordinator (indoor weather satellite) needs to be up and running before any other module is powered up.

Load the Maxstream X-CTU software, select the USB development board, and hit the Terminal tab. Make sure you select the 9600 baud rate. The terminal should display various pieces of telemetry as shown in Figure 19. While the data may not be valid at this point, it does tell us that the three satellites are working together properly.

Connecting Your 1Wire Network

I like to perform some basic tests before I mount my outdoor equipment, just to make sure things are working properly. To do this, I mount my anemometer and wind vane on a small pole attached to a small piece of wood for support as shown in Figure 20. This allows me to perform tests in my lab before moving outdoors. This way, if I have problems once I move the gear to the weather pole, I know it's simple wiring issues.

To connect the 1Wire network to the satellite, I use a small surface mount box like the one shown in Figure 21. I wire a two-pin female header to the red and green terminals on the bus. The red terminal should be connected to the data lead on your satellite's 1Wire network interface. In the case of the regulator interface, the outside pin closest to the coax connector is the data lead. The pin closest to the data lead is the GND lead.

If your weather instruments are already mounted on a pole, you can run a

PROGRAM 1

```
DiosPro
'ModuleTest.txt
func main()

    print "Start Outside Weather Test"
    hsersetup baud,HBAUD9600,start,txon,inwait,500

loop:
    print "Outside Temp: 99F"
    hserout "Outside Temp: 99.9F",13
    pause 3000
    goto loop

endfunc
```

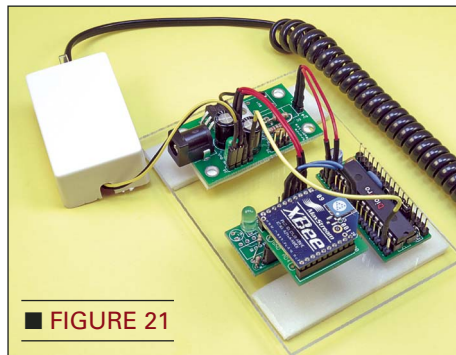


FIGURE 21

cable from your sensors to the satellite to perform your tests.

Performing a Network Search

In order to read the 1Wire sensors, you will need to obtain the ROM serial numbers from each of the sensors on the network. Included with the downloads for this project is a program called OutDoorSearch.txt. With the AAG weather instrument connected to your satellite, load and run the OutDoorSearch.txt program. If your sensors are connected properly, the data from the three sensors should be displayed as shown in Figure 22.

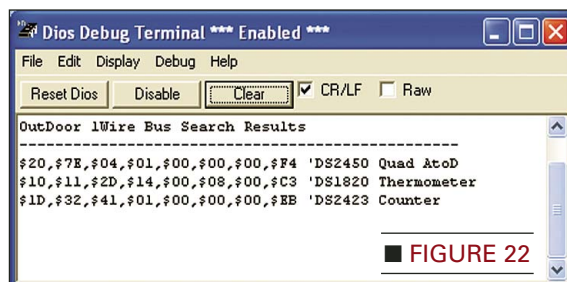


FIGURE 22

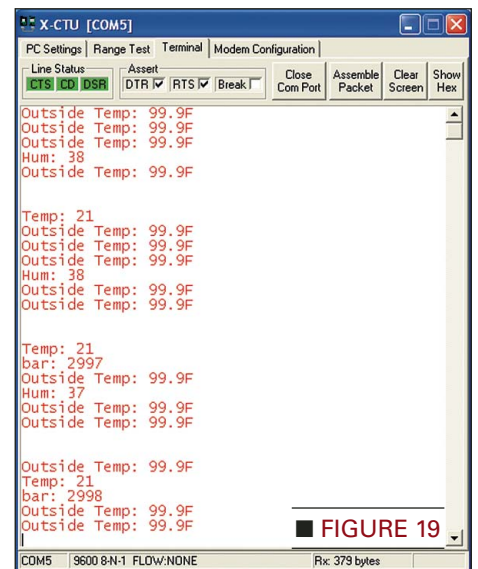


FIGURE 19

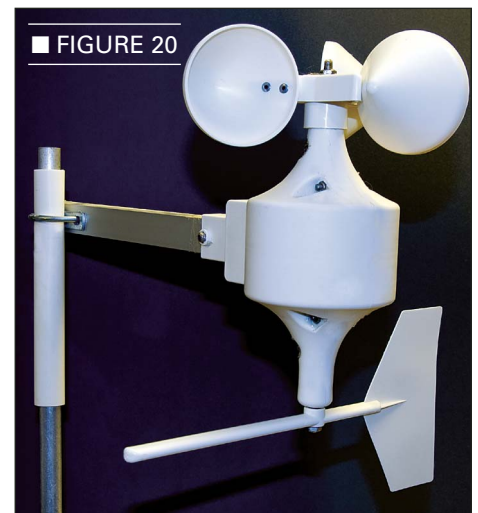


FIGURE 20

The wind vane uses the DS240. The anemometer uses the DS2423. Keep this in mind when you make

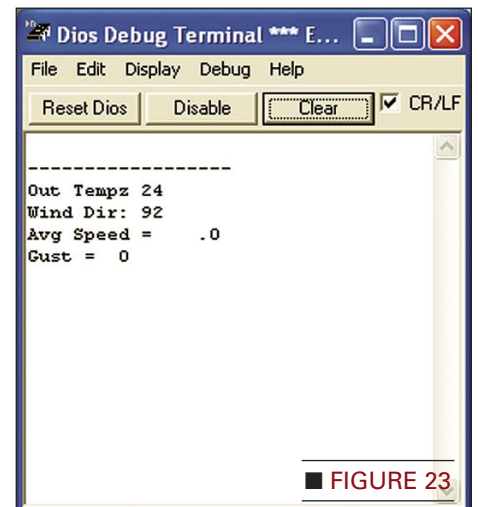


FIGURE 23

The following is a breakdown of the sources for all the components needed for Parts 2 and 3 of this project.

MAXSTREAM

- Starter Kit #XB24-DKS
http://store.maxstream.net/index.cfm?fuseaction=product.display&Product_ID=1

Also available from Mouser
www.mouser.com/search/ProductDetail.aspx?R=XB24-DKSVirtualkey61440000virtualkey888-XB24-DKS

Or do a search for XB24-DKS

KRONOS ROBOTICS

- DiosPro 28 Chip
www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16429
- Dios Carrier 1
www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16170
- 3.3V to 5V Interface Kit
www.kronosrobotics.com/xcart/cus

www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16537

- 40-Pin Male Header
www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16290
- 1K Resistors
www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16178
- Regulator Kit
www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16304
- Free Dios Compiler (Includes 1Wire libraries)
www.kronosrobotics.com/downloads/DiosSetup.exe

HOBBY BOARDS

- Wind Instrument
www.hobby-boards.com/catalog/product_info.php?cPath=22&products_id=92
- Humidity Module (H3-R1-A)
www.hobby-boards.com/catalog/product_info.php?cPath=22&products_id=46
- Lightning Detector
www.hobby-boards.com/catalog/product_info.php?cPath=22&products_id=65

SPARKFUN ELECTRONICS

- XBee Breakout Board (Used to build various interface boards)
www.sparkfun.com/commerce/product_info.php?products_id=8276
- 2 mm Connectors (You need two for each breakout board)
www.sparkfun.com/commerce/product_info.php?products_id=8272

SCHMARTBOARD

- Prototyping Board (.1")
www.schmartboard.com/index.asp?a=11&id=24
- Jumpers 5" Yellow
www.schmartboard.com/index.asp?a=11&id=42
- Jumpers 3" Red
www.schmartboard.com/index.asp?a=11&id=41

HARDWARE OR HOME CENTER

- Double Sided Tape
- PlexiGlass (or equivalent)
- Hook and Loop Tape
- Outdoor Enclosure and Cover (Check the Electrical section)

changes to the OutDoorSensorTest.txt program to add the ROM addresses.

Load the OutDoorSensorTest.txt program and modify the three ROM addresses to match that of your ROM Search. Load the program into the DiosPro and every 10 seconds or so,

the DiosPro will take a reading and spit out the results to both the debug terminal and the XBee mesh network. If you connect your PC to one of your development boards and run the X-CTU software in terminal mode, you should be able to see the network data.

Mounting the Outdoor Satellite

The way you mount your enclosure will depend on the type of weather pole you have built. You can find detailed instructions on how

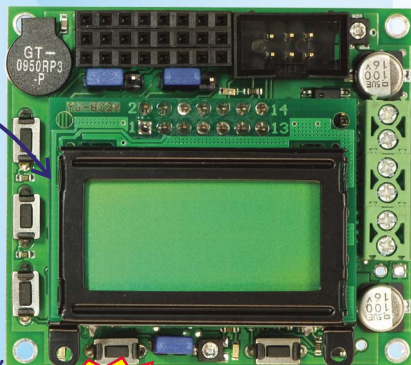
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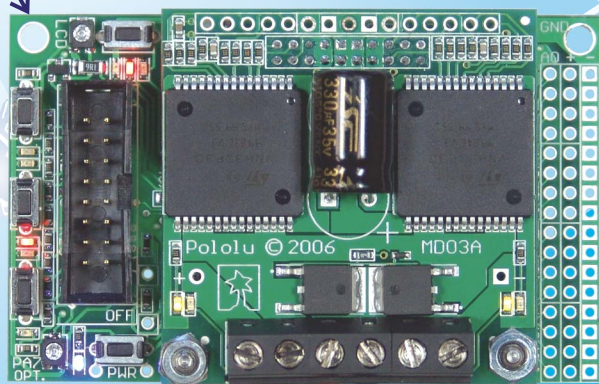
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to build your own weather pole at www.kronosrobotics.com/Projects/WeatherPole.shtml.

When you mount your enclosure, make sure the entry hole is located on the bottom as shown in Figure 24. Your power and network cable will enter through this hole. Small headers were placed on the ends of the cables and attached to the regulator in the positions shown. All you need to run from the pole is a single set of wires. On the opposite end of these wires, I have a 12VAC adapter wired. Make sure that +12V is connected to the wire that is labeled VIN on the regulator. The negative lead on the AC adapter is connected to the wire that attaches to VSS on the regulator.

Due to the range and position of my XBee module, I could not get enough range to communicate with my mesh network inside my house. I attached a small wire to the antenna lead (see Figure 24). This wire is run outside the box and is long enough to clear the pole for a clean line of sight to my indoor

LINKS

- **Hobby Boards:** www.hobby-boards.com
- **SparkFun Electronics:** www.sparkfun.com
- **Kronos Robotics:** www.kronosrobotics.com/xcart/customer/home.php
- **SchmartBoard:** www.schmartboard.com/index.asp?a=11&page=a_products
- **Jameco Electronics:** www.jameco.com

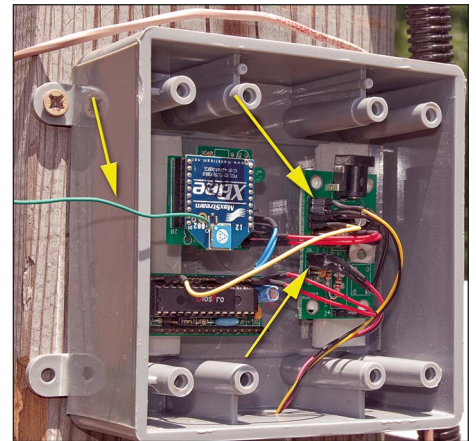
weather satellite that is located on a window sill that faces my weather pole.

Final Thoughts

It is important that you use some sort of Velcro or hook and loop to attach your satellite module to the enclosure. I assure you that at some point you are going to need to update the firmware in the DiosPro chip.

What's Next

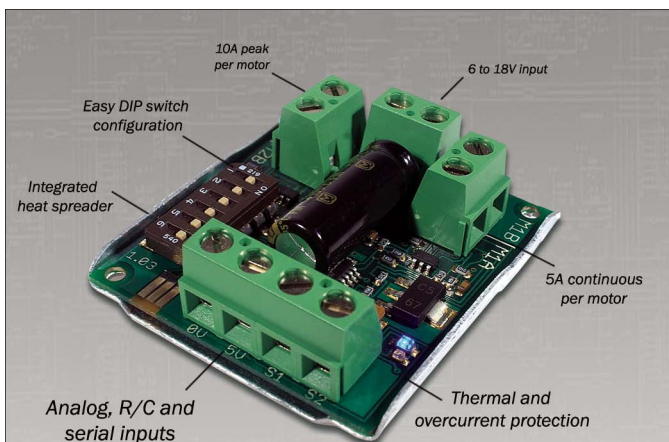
The last step in the wireless weather



■ **FIGURE 24**

station is for me to walk you through the protocol that I created. This protocol is the heart of the wireless station, and will allow you to add your own sensors and display units to the network. I had planned on covering the protocol in this article but just did not have the space. Next month, I promise.

Be sure to check for updates at www.kronosrobotics.com/Projects/wirelessweather.shtml. **NV**



*** Kitchen sink not included.**

Sabertooth 2X5 \$59.99

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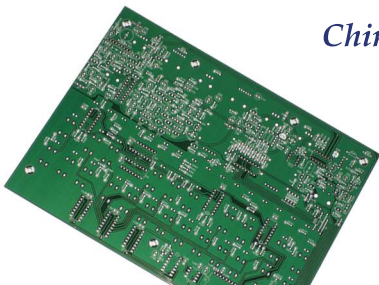
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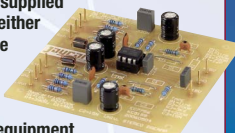


Universal Stereo Preamplifier Kit

KC-5159 \$10.95 + post and packing

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Requires 12VDC wall adaptor (Jameco #252751 \$12.05)

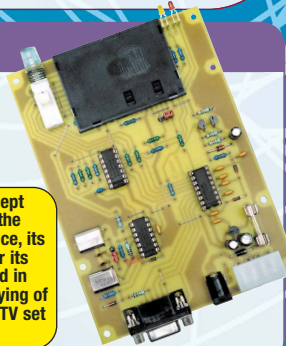


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Requires 9-12VDC wall adaptor (Jameco #252751 \$12.05)



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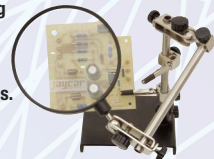
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Anytime you need that extra bit of help with your PCB assembly, this pair of helping hands will get you out of trouble. With a 90mm magnifying glass, it also provides an extra pair of eyes.

- Size: Base: 78 x 98mm
- Height: 145mm



Resistance Wheel

RR-0700 \$10.00 + post and packing

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Jaycar Electronics



In recent years, more holiday lights have appeared in our neighborhood around Christmas. These are a combination of traditional strings and newer lawn displays, some with animation or inflated by electric fans, but all purchased from large retailers. For some time, we've put our own light displays up

so it was time to "up the ante" a bit with computer automation.

HOLIDAY LIGHTS

A quick search online and in dedicated news groups revealed that while some amateur displays use commercial lighting controllers, many use a dedicated PC and modular hardware. However, none were scaled to our budget and expectations. This construction project fills those needs and is flexible for future expansion or adaptation.

This is an outdoor electric display that will face all kinds of weather conditions, so it must be safe and reliable. It also needs to be built tough so it lasts for many years. Using existing raintight electrical trade materials where possible, it can be constructed with hand tools and electronics hobby level skills.

The project has two elements: a control cabinet that houses the electronics and several similar lighted ornaments connected by multi-core cables. In my case, there are 16 mini-trees (about 30 cm or one foot high), each with a string

of 50 mini-lights and a C5 topper bulb, which are simply staked into the lawn. This gives 32 channels to play with! Each channel can be set to any brightness or turned off by the control program.

Another important feature is a real time clock (RTC) with battery back-up that turns the display on and off each night, saving a dedicated timer or a human 'keeper' to be present all the time. What the light show does and how long it runs is entirely up to the user. After some thought and experience from similar projects in previous years, I concluded there are basically two ways to approach the design; both use a microcontroller (an Atmel AVR, in this case) and multiple 120V AC output channels controlled by robust triacs.

First, a lighting pattern can be calculated in real time; a simple marquee chaser is a good example. Second, a predefined pattern can be stored in memory and executed as the display runs, and then repeats. In this way, a light show with animation elements can be programmed, and may include random elements to avoid the "mechanical effect" seen in some commercial displays.

This project caters to both programming methods, which will be described later. Before we get ahead of ourselves, though, let's take a look at the common hardware.

System Description

Refer to Figure 1. The control cabinet contains five PCBs. Four are I/O (input-output) channels that each control eight channels and the fifth PCB is a controller with the microcontroller,

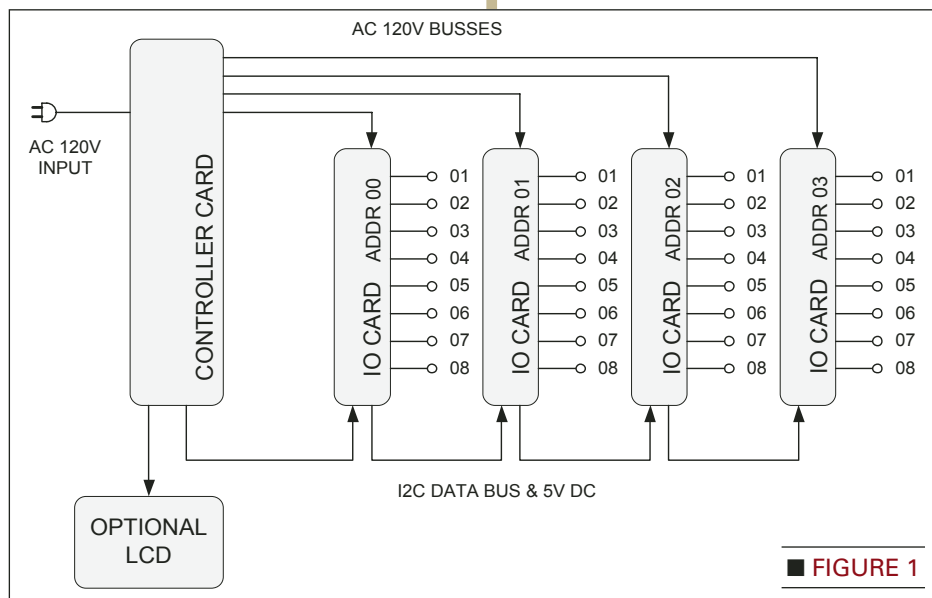


FIGURE 1

user interface, RTC, and power supply. Fewer I/O boards can be employed, if desired, down to the minimum of one, giving eight channels.

This makes the basic design attractive for smaller displays or indoors to spice up a Christmas tree. The use of smaller PCBs also makes the packaging a bit easier, and the entire system is built into a NEMA raintight steel enclosure found at any local home improvement store.

User Interface

Once the system is completed and installed, it requires no further attention. The RTC will turn it on and off each evening, which leaves just the task of setting it up initially. There is a push switch on the PCB to reset the μC (but not destroy the RTC settings), should a reboot be needed. We have eliminated the power on-off switch and the long AC cord that may be plugged in away from the cabinet and therefore inconvenient to reset.

An LCD port is included on the controller PCB for connection to an industry standard module, such as the popular 16 x 1 type. This is not needed when the system is running outdoors, so I didn't add it to the cabinet hardware. It does come in handy for field resetting of the RTC, which can also be done by downloading a new firmware image over the AVR ISP programming port. But, this option is not as attractive when the system is installed outdoors.

I/O Card

Refer to Figures 2 and 3. The I/O card consists of eight identical opto-isolated AC channels and a decoder IC that links to the other cards and controller over an I²C (eye-squared-see) data bus. A DIP switch on each I/O card selects the address of that card and, if desired, two or more cards can have the same address (if a large display needs more current than a single card's limit of five amps).

Each output channel has a monitor LED (yellow), plus another LED (green) to

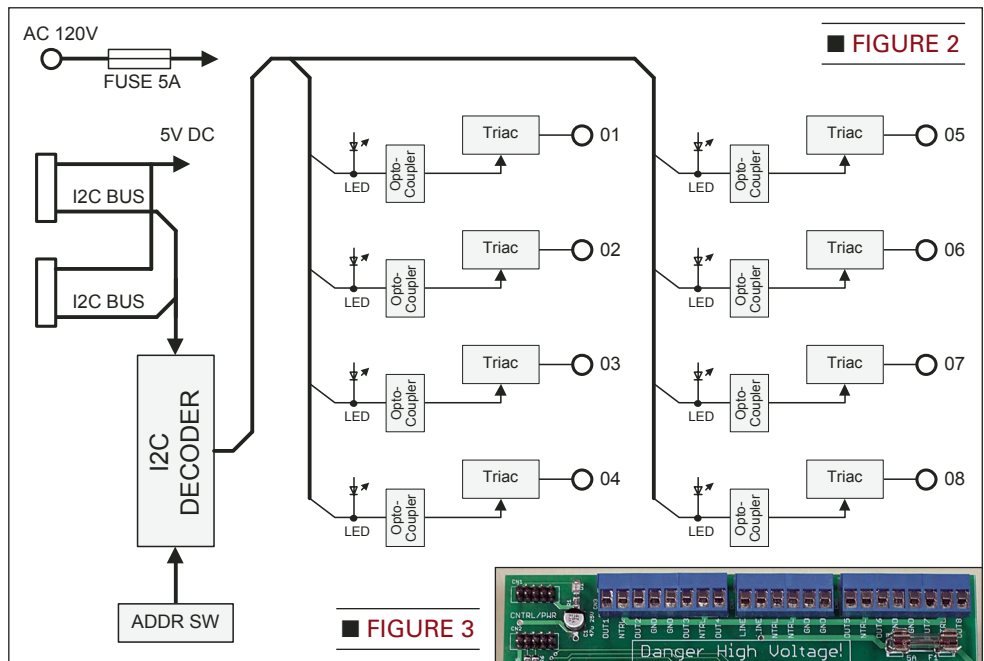
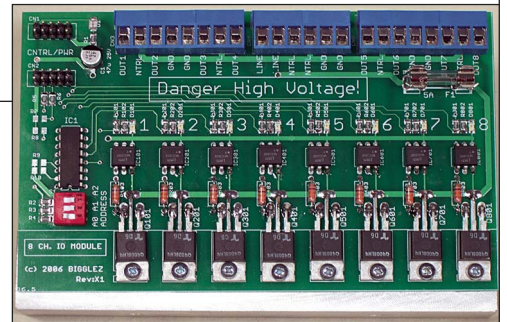


FIGURE 2

FIGURE 3

indicate DC power is available over the ribbon cable data bus. I found these to be invaluable for field installation and testing as one might be doing the installation outdoors on the lawn or up a ladder in the winter weather.



I/O CIRCUIT DESCRIPTION

The I/O PCB contains eight identical channels of AC load control using triacs, which are fed via F1 with 120V AC from CN4. The triac trigger circuit was made as simple as possible, and uses an opto-coupler to isolate the hot AC circuits from the ground referenced DC control circuits. Component references for each channel are offset by 100, so R101, R201, R301 represent "R1" in channels 1, 2, and 3, respectively. We'll use Rx01, Rx02, etc., below to refer to all eight channels.

The triac, Ox01, has a TO-220 package and is attached to the bracket as a heatsink. Because each I/O card is power limited to controlling about 600 watts (limit of 5A at fuse, F1), the triac does not need heatsinking, unless one channel carries the full load power. Note that electrically isolated tab triacs are required, so the devices can be attached directly to the metal mounting screw and metal bracket (which is grounded through the cabinet).

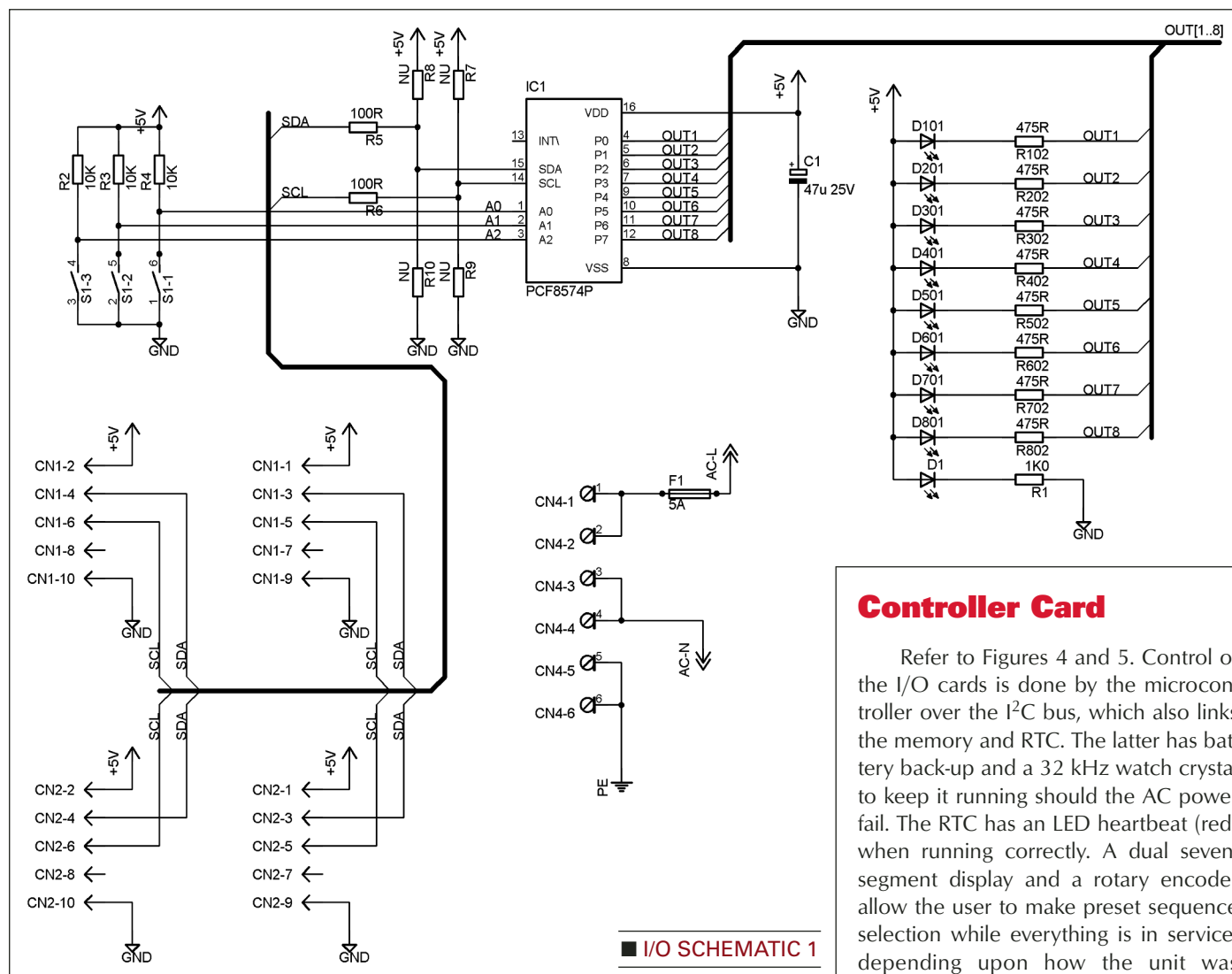
Each opto-coupler, ICx01, has a photo diac, which can conduct in either direction when the associated internal LED is turned on. This allows the triac to fire on both polarities of the AC waveform. Current to fire the triac is limited by the 330 Ω resistor, Rx03, on the hot side. The downside to this scheme is that the AC waveform must rise above or below zero before there is enough current to

fire the triac. Not a big problem as the early firing of the triac represents full brightness of the controlled lamps. If the lamps operate at, say, 97% power instead of 100%, no one will notice. At the end of each AC half-cycle, the voltage reverses and releases any triacs that were turned on earlier in the half-cycle.

Current for each opto-coupler LED is supplied by the I²C decoder, IC1. It has eight channels of open drain outputs, and each sinks current for the opto-coupler and the monitor LED for that channel. Current is limited for the opto-coupler by Rx01 and the LED by Rx02, respectively.

The decoder IC receives data over the I²C bus via connectors CN1 and CN2 which are in parallel and serve to daisy-chain the I²C bus to other cards. Resistors R5 and R6 isolate the decoder IC from the bus, and termination resistors (R7-R10) were added but are not needed.

There is a DIP switch on each card to shift the address range for the I²C decoder IC. All I²C components listen to all messages on the bus, but only correctly addressed messages are acted upon. I/O cards require setting of the DIP switches prior to installation in the system, and all eight possibilities (three binary address lines) were included so the same I/O card design can be reused for other projects.



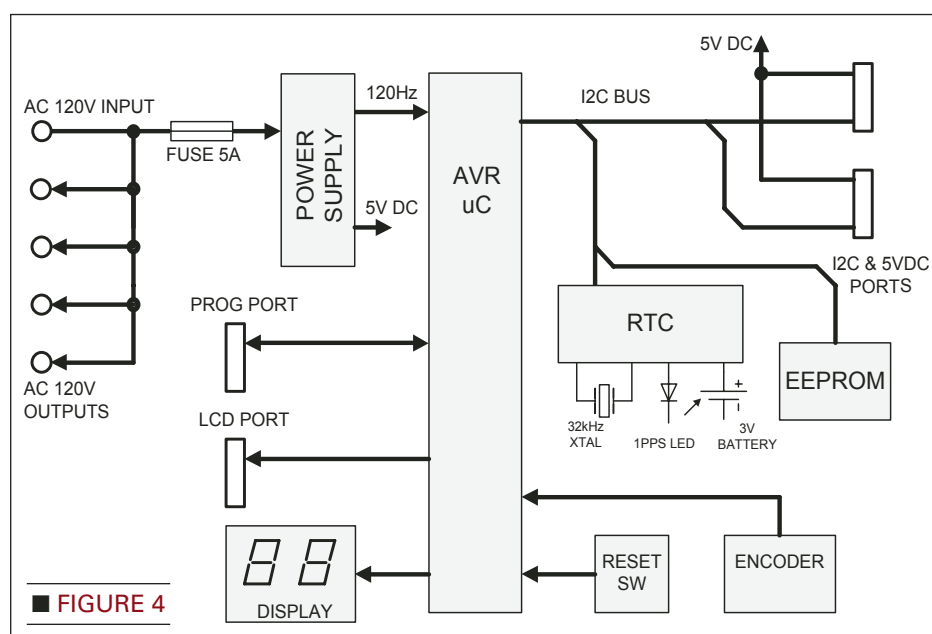
Controller Card

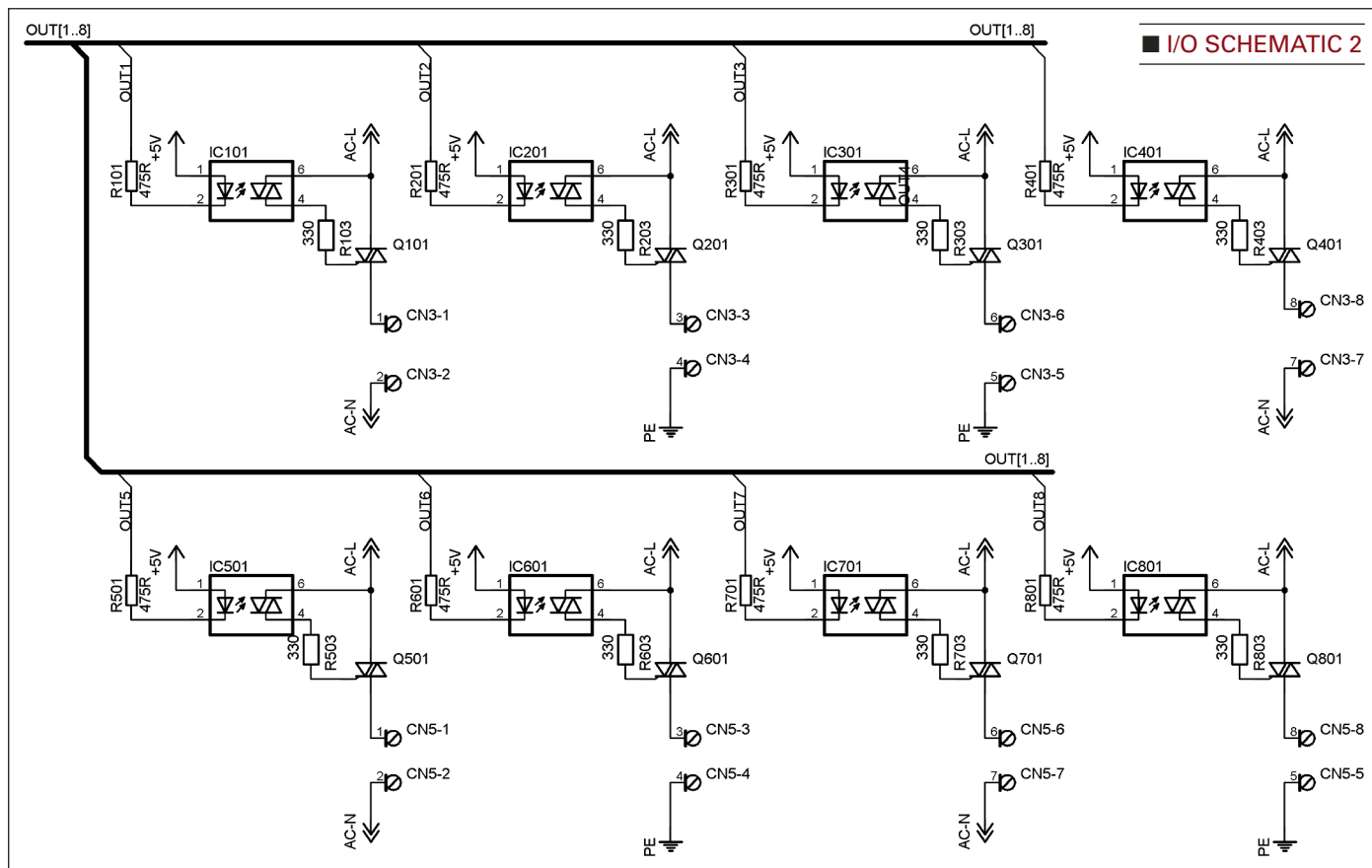
Refer to Figures 4 and 5. Control of the I/O cards is done by the microcontroller over the I²C bus, which also links the memory and RTC. The latter has battery back-up and a 32 kHz watch crystal to keep it running should the AC power fail. The RTC has an LED heartbeat (red) when running correctly. A dual seven-segment display and a rotary encoder allow the user to make preset sequence selection while everything is in service, depending upon how the unit was programmed during construction. Both the microcontroller and the EEPROM are in sockets, so it's easy to make upgrades and experiment with the lightshow timing once the installation is complete.

Dimming the individual channels is done by phase control of the triac trigger. The microcontroller needs to know when the AC crosses zero on each half-cycle, so the INT0 (interrupt0) is tripped by the 120 Hz derived from the power transformer. Driving 32 channels and their LED monitors along with the microcontroller hardware requires a one amp, five volt supply.

Electronics Cabinet

Refer to Figure 6. A heavy duty steel cabinet holds all of the electronics. Each of the I/O cards attaches to a metal





bracket — made from readily available, one-inch aluminum angle — which serves as the mounting and heatsink. For most applications, a heatsink is not needed because the triacs dissipate approximately one watt each for a one amp load. The same bracket design is used for the controller card, which has a 5V linear regulator mounted on the PCB and bracket.

The cards were installed and wired together, using either ribbon cables (5V DC and I²C) or short lengths of stranded 14 AWG wire (culled from the extension cord used for the AC input). Note that not all of the terminals are used, but were added for flexibility in other projects using these cards.

When the cabinet is installed outdoors and wired to the lights (mini-trees in my case), each cable is routed through a raintight Heyco bushing and to the screw terminals on the I/O cards. This is a bit of a knuckle buster; patience is required, but the end result is reliable and cost effective. (I could not find affordable outdoor connectors with four circuits to make this chore a snap). After all, this

CONTROLLER CIRCUIT DESCRIPTION

The controller PCB contains the power supply and μ C, user controls, along with the RTC circuit and the EEPROM. AC power is applied at CN2 and distributed to the I/O cards via CN1 and CN3, and also to the transformer, T1, via fuse F1. The output from the transformer is rectified by BR1 and feeds C1 via diode D1. The anode of D1 has a 120 Hz half-wave voltage that is used by the μ C for sync, and that signal is developed by R23 and R24. Five volts for the remaining circuits are regulated by IC1, and decoupled by C2.

IC4, the AVR Mega8, is connected to all the other circuits and runs from its internal 8 MHz clock; accuracy is not needed as the RTC has crystal control and the triac timing is derived from the 120 Hz sync just described. The RTC, IC2, is self-contained and uses a 32 kHz watch crystal, X1, and a battery, B1, to keep time if the AC power fails. RTC data is transferred over the I²C bus which is also shared with the EEPROM, IC3, and the I/O cards connected by ribbon cables.

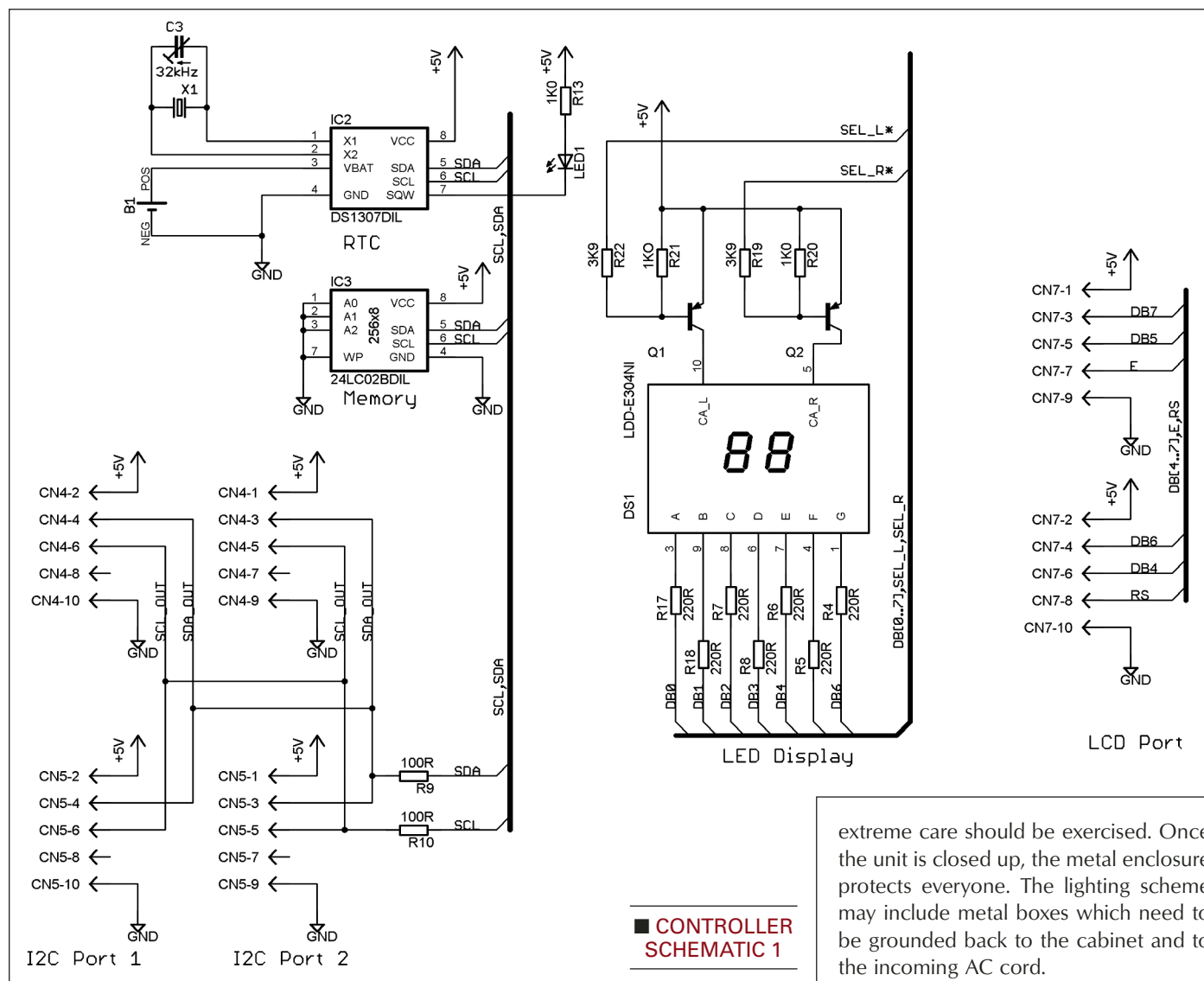
I²C was originally applied in consumer electronics (such as VCRs and TV sets) for PCB to PCB data flow, and care was taken here to reliably extend the bus over ribbon cables to the I/O cards. Resistors R9 and R10 were added to isolate the external bus, and resistors R11, R12, R14, and R15 follow the recommended I²C bus terminations.

Programming of the AVR can be done in-circuit with the AVR ISP, and this connects to CN6. Notice that the older style 10 pin arrangement is used; after this project was completed, the AVR ISP mkII (USB format) was released and I have upgraded to the current model that only uses a six pin header. A simple 10 pin to six pin cable can be used to connect the newer six pin ISP pod.

Inputs to the system come from an encoder with a switch, S1, and a second switch, S2, that can reboot the AVR by lowering the Reset line. R16 keeps the reset line high when inactive. The encoder has two quadrature phase outputs: A and B. Firmware determines the direction and amount of movement on the encoder shaft.

An external LCD module can be added to the system; power and data for it are sent out from CN7, on a data bus that is shared with the LED display segments.

Finally, the dual LED display anodes are driven by two transistors. This greatly reduces the amount of hardware! Because the LCD and LED are multiplexed, care is taken in the firmware to address each one separately. The LED is a dual digit component that is also MUX'd internally, so two select signals (SEL_L and SEL_R) are used with high side driver transistors Q1 and Q2, respectively, to select the correct LED digit.



extreme care should be exercised. Once the unit is closed up, the metal enclosure protects everyone. The lighting scheme may include metal boxes which need to be grounded back to the cabinet and to the incoming AC cord.

only gets done once or twice a year.

The cabinet was staked to the lawn using two lengths of EMT conduit attached to the cabinet base. The same technique was used for the mini-tree bases. Alternatively, the cabinet can be mounted on a wall.

Safety Warning

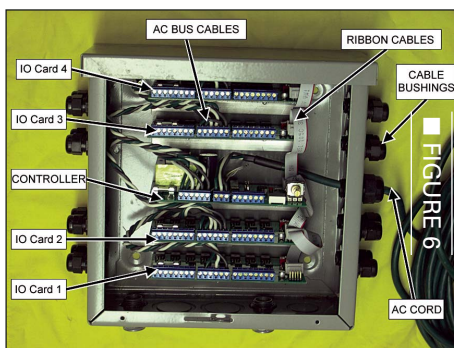
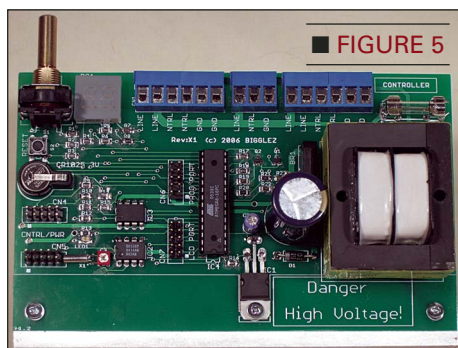
Anyone attempting to construct and use this equipment should be aware of a few safety issues. AC power is conducted through both PCBs and when the cover is off, there is a deadly shock hazard, so

Circuit Protection

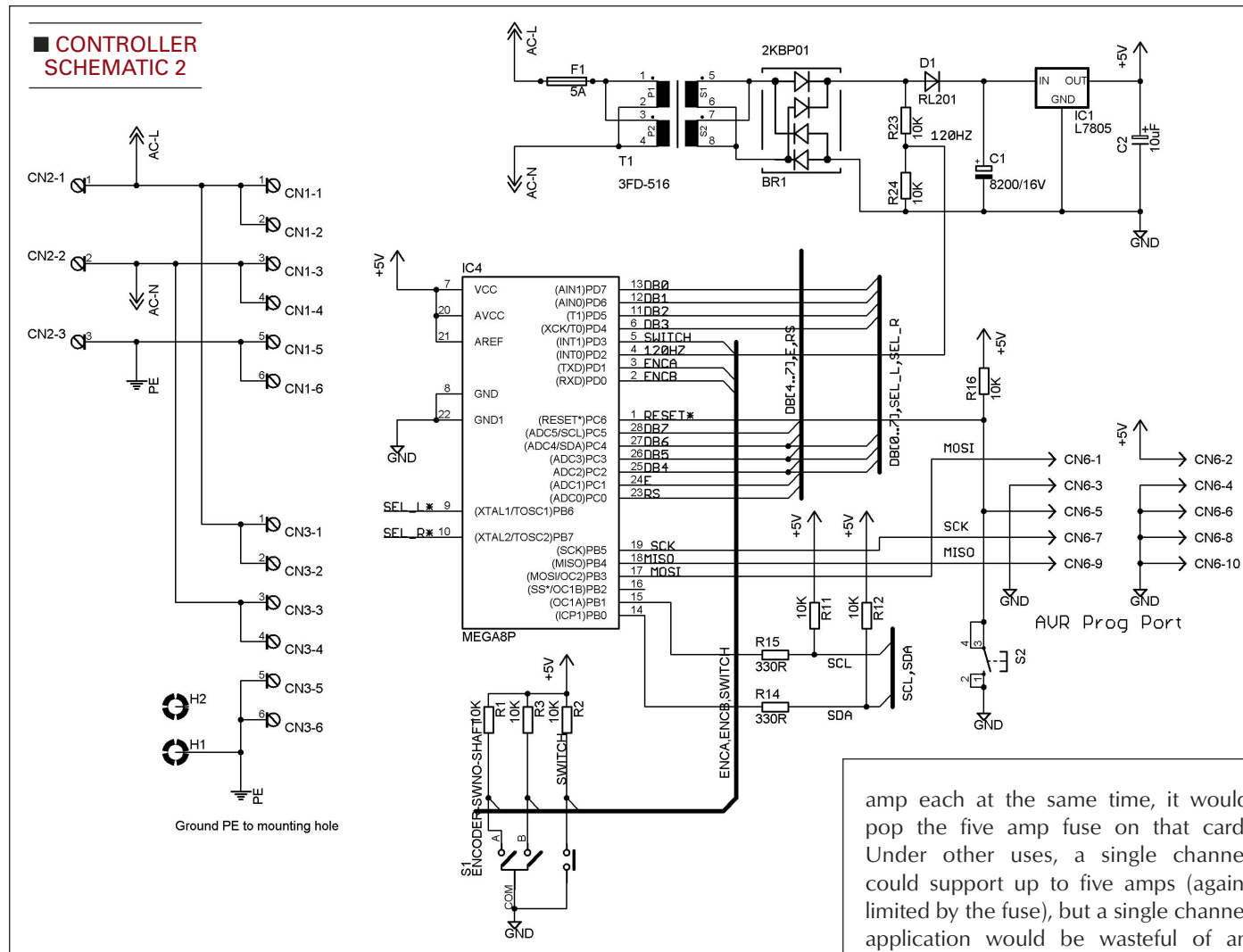
Holiday lights are prone to failure, possibly by damage to the wiring or breakage of the bulbs. Some 120V bulbs may short out when the filament breaks, and this can cause a current surge. Each I/O card is protected by a five amp fuse, as is the controller card's power transformer. I hard-wired the mini-lights on each of my trees, cutting off the original plugs. Note that these had fuses installed in the plugs, and that protection is continued by the fuses on the I/O cards as just noted.

Power Ratings

In theory, all channels could be turned on at the same time and a total of



CONTROLLER SCHEMATIC 2



amp each at the same time, it would pop the five amp fuse on that card. Under other uses, a single channel could support up to five amps (again, limited by the fuse), but a single channel application would be wasteful of an eight channel card!

The important point is that a correctly designed installation will allow all lights to come on safely, and each branch (I/O channel) should

approximately 20 amps drawn from the AC input. The wiring should be sized accordingly, preferably with 14 AWG or larger conductors. The incoming AC cable and standard grounded plug were salvaged from a heavy duty outdoor extension cord, which should be made long enough to reach a sheltered (preferably CGFI protected) outlet in your home or in a raintight enclosure outdoors.

In practice, the light show draws a lot less average current, so for piece of mind, the wiring, PCB traces, and fusing scheme were designed for the worst case loading. Depending upon the application, different light strings can be installed and typically several strings may be daisy-chained together on each channel. Recently-introduced LED strings draw a lot less power, mini-lights more, and the older strings of C7-1/2 (5W

bulbs) or C9-1/4 (7W bulbs) draw the most. Figure 7 shows the ratings for common bulbs and strings.

If all channels on a card drew one

Typical mini-lights are rated at 2.4V and wired in series or series/parallel. They draw different current depending on "standard," "energy saving," or "super bright" bulbs, as follows:

Type	Bulb Current	Bulb Power	Power Per String
Super Bright	200 mA	480 mW	16.8W/35
Standard	160 mA	384 mW	13.44W/35
Energy Saving	100 mA	240 mW	8.4W/35
Single LED	20 mA	48 mW	1.68W/35

Note: LEDs consume only 10% (1/10th) of super bright, 12.5% (1/8th) of standard, and 20% (1/5th) of energy saving strings of mini-lights, all other things being equal.

Parallel connected strings use 120V lamps, as follows:

Type	Bulb Current	Bulb Power	Amps Per String	Power Per String
C7-1/2	40 mA	5W	1.0	125W/25
C9-1/4	60 mA	7W	1.5	175W/25

FIGURE 7



SYSTEM LEVEL PARTS LIST

ITEM	PART NO.	QTY	SUPPLIER
For Cabinet			
<input type="checkbox"/> NEMA 3R Box	RSC101004	1	Home Improvement Store
<input type="checkbox"/> Controller PCB, complete	See Figure 5	1	
<input type="checkbox"/> I/O PCB, complete	See Figure 3	4	
<input type="checkbox"/> Bracket	See Figure 8	5	
<input type="checkbox"/> EMT Bushing (for stakes)		2	Home Improvement Store
<input type="checkbox"/> EMT Conduit (for stakes)	1/2in by 24in	2	Home Improvement Store
<input type="checkbox"/> EMT Nut (to fit Heyco Bushing 3231)		1	Home Improvement Store
<input type="checkbox"/> Heyco Bushing 3231	836-8231	1	Mouser www.mouser.com
<input type="checkbox"/> Heyco Bushing 3238	836-8238	16	Mouser
<input type="checkbox"/> Heyco Nut 8461	836-8461	16	Mouser
<input type="checkbox"/> Screw, Philips, 4-40 x 0.250		35	
<input type="checkbox"/> Washer, Lock, 4-40		35	
<input type="checkbox"/> Screw, Philips, 8-32 x 0.375		10	
<input type="checkbox"/> Washer, Lock, 8-32		10	
<input type="checkbox"/> Ribbon Cable, 10 pin x six inches		4	Digi-Key www.digikey.com
<input type="checkbox"/> Wire, 14 AWG, Blk x eight inches		4	
<input type="checkbox"/> Wire, 14 AWG, Grn x eight inches		4	
<input type="checkbox"/> Wire, 14 AWG, Wht x eight inches		4	
<input type="checkbox"/> LCD Module 16 x 1 (optional)		1	
<input type="checkbox"/> LCD Ribbon Cable (optional)	See Figure 10	1	
For Mini-Tree (to build one)			
<input type="checkbox"/> Mini-Tree (12 inch or taller)		1	Target or Wal-Mart www.target.com www.walmart.com
<input type="checkbox"/> Socket, Candelabra	SO267	1	Grand Brass Lamp Parts www.grandbrass.com
<input type="checkbox"/> Bulb, 120V 5W, G40, C7 1/2		1	
<input type="checkbox"/> Single Gang Four-hole Weatherproof Box	333500	1	HD Supply www.hdsupply.com
<input type="checkbox"/> Single Gang Weatherproof Blank Plate	332000	1	HD Supply
<input type="checkbox"/> EMT Bushing (for stake)		1	Home Improvement Store
<input type="checkbox"/> EMT Conduit (for stake)	1/2in by 24in	1	Home Improvement Store
<input type="checkbox"/> Heyco Bushing 3231	836-8231	3	Mouser
<input type="checkbox"/> Wire Nut (16-20 AWG)		4	
<input type="checkbox"/> Grounding Screw, #10, Green		1	
<input type="checkbox"/> Cable, Four Conductor 18 AWG (100 ft spool)	566-8489-100		Mouser
<input type="checkbox"/> Mini-Light String, 50 bulbs		1	
<input type="checkbox"/> Cable, 18 AWG, twin zip cord		2ft	
<input type="checkbox"/> Heatshrink, various sizes		A/R	
<input type="checkbox"/> Caulk, Silicone			

not be overloaded.

Construction

There are three stages to construction, and these will vary depending on the type and size of display desired. Remember, each bank of eight channels needs an I/O card, and each system (up to four I/O cards) needs a controller. The system described here uses all five cards (four I/O cards for 32 channels and one controller card). It's easier to test the I/O cards after the controller card is working. I wrote simple routines to exercise different functions during development, and these tools (code) are available for downloading from the *Nuts & Volts* website (www.nutsvolts.com). I will provide the detailed description of the circuits and software last, so constructors can jump in and start building, if they prefer.

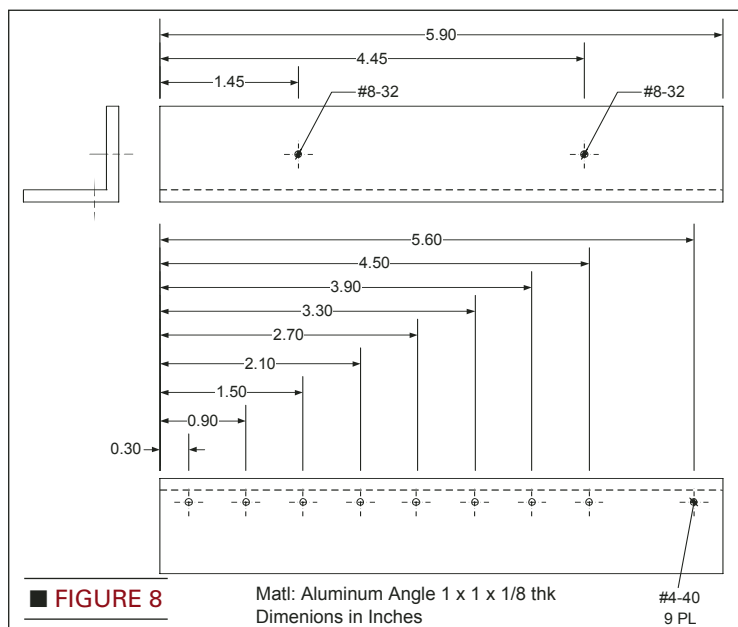
The first stage is building up the PCBs and bench testing them. Next, the cabinet and wiring should be done, and lastly — if used — the mini-trees get assembled. All of this is going to take some time. I found that wiring the mini-trees took the longest and could be done in front of the television over several evenings. Most of the work is hand assembly and installation of tie-wraps, and can also be done in batches like a small production line. If your design won't include mini-trees or similar, skip this step. Perhaps you will

have strings of rope lights or regular outdoor holiday lights connected directly to the controller.

PCB Assembly

Both PCB types require through hole and SMT parts. SMTs were used to compact the design and can be hand soldered just like the through hole ones. Sockets are used for some ICs to allow field firmware replacements, and many of the power parts are physically large and require a hot iron to make good solder joints. All the components are installed on one side, and it's smart to put the SMTs on first. I use paste solder from a syringe and a hot air gun to mass solder all the SMTs at once. Working with SMT parts is not so hard; probably the only lesson to learn is that very tiny amounts of solder are needed compared to through hole construction.

After assembly, inspect all the soldering and clean any flux off. Use care to eliminate any bridges or splashes of solder, more so than usual as this design carries AC line



CONSTRUCTION OF THE MINI-TREES

My mini-trees started as a concept to fill a small lawn with "many trees." The actual trees were purchased new at a post-Christmas store sale, and the project moved forward with 16 assemblies. At that quantity, it was clear that the budget and time available would favor a simple construction method. Another decision was to install two circuits on each tree; the topper bulb and conventional mini-lights. A string of 50 clear bulbs worked well. The controller would require 32 channels to cover everything.

There are two foot trees with similar construction available, which could be used here. They would require a string of 100 mini-lights to get about the same density.

CONSTRUCTION

As shown in Figure A, the trees are staked to the ground with a length of EMT conduit and a raintight outdoor cast metal junction box. The supplied plastic tree stand was discarded and the tree spine fitted to a Heyco bushing that fits the already threaded hole in the junction box (known as a hub in the trade). It might be necessary to enlarge the diameter of the tree spine, using a layer of heat shrink tubing. A junction box with four holes was chosen so that the EMT spike fits the bottom and the electrical cable to the controller exits from the back. The final hole on the top is for the wiring from the tree, through another Heyco bushing. Finally, the junction box is closed with a raintight cover.

Internally, the four conductor cable is connected to the mini-lights (after the original plug was removed) and also to the zip cord used for the topper light, using standard wire nuts. The fourth wire is bonded to the junction box and to a drain wire attached to the metal spine of the tree. All

metal is therefore grounded in case something goes wrong while the power is on.

The mini-lights are attached to the branches with cable ties, placing the bulbs as near to the ends of the tree branches as possible. It's easier to put the wiring for the topper lamp on first, then start the string at its free end, winding down to the base. Many strings have end-to-end connectors, and if used here, the socket end is tied off near the tree top, which is less work than cutting the wires and insulating them (use heat shrink tubing if the connector is chopped off).

TOPPER LAMP

A variety of candelabra lamps can be used; I tend to favor the G40 (1-1/2 inch/40 mm globes) rated at 5W. Much brighter lamps (there are some 40W and 60W flame shaped bulbs for chandeliers) would overpower the final display. The channels for the larger bulbs can be toned down with the controller's dimmer function, if desired.

I used an outdoor rated single candelabra socket, which attaches to a zip cord without tools available from Grand Brass Lamp Parts (www.grandbrass.com). The zip cord 'tail' was folded over and heat shrink tubing applied for safety (and to keep the rain out).

Another method would be to scrap a string of C7 1/2 holiday lights and take the sockets. This is a bigger effort as the single sockets would require extension wiring. I had no luck in trying to remove and replace the original wiring to this type of socket which latched closed. Too many were broken trying to rework them.

TESTING

It's a good idea to power up the mini-trees before connecting them to the



controller. A simple cheater cord can be made from an old lamp cord. Since the original fuse (in the mini-light's plug) was removed, the cheater cord should have a fuse of its own or a standard 60W bulb in series to protect against a wiring error or dead short. The mini-lights should be steady burning, which is usually the case when new, but make sure that a thermal flasher lamp was not installed in the string.

The mini-trees are not so attractive during the day, but come to life when the sun goes down and the holiday lights go on!

voltages on some PCB traces.

Power-Up Testing

The controller card has a five volt power supply and requires 120V AC input, which can be provided by a lamp cord for bench checkout. It's a good idea to cover the exposed AC traces with electrical tape when working with this arrangement. The 5V rail should be within 5% (4.75 to 5.25V) at the regulator output; there are no adjustments on the card.

By using a PC and an AVR ISP pod, the test programs can be downloaded to the AVR uC. These bring up the RTC, which will flash the red LED at 1 PPS (one pulse per second).

The LED display will respond to

I/O BOARD PARTS LIST

ITEM	VALUE	PART NO.	DESCRIPTION
□ C1	47µF 25V	PCE3185CT-ND	Electrolytic cap SMD
□ CN1	HDR2X5	A26573-ND	Conn Header Vert .100 10POS 15AU
□ CN2	HDR2X5	A26573-ND	Conn Header Vert .100 10POS 15AU
□ CN3	OSTTB06	ED2574-ND	Terminal Block 5MM HOR 6POS PCB
□ CN4	OSTTB06	ED2574-ND	Terminal Block 5MM HOR 6POS PCB
□ CN5	OSTTB08	ED2575-ND	Terminal Block 5MM HOR 8POS PCB
□ D1	Green	160-1404-1-ND	LED Green Clear 1206 SMD
□ D101	Yellow	160-1406-1-ND	LED Yellow Clear 1206 SMD
□ D201	Yellow	160-1406-1-ND	LED Yellow Clear 1206 SMD
□ D301	Yellow	160-1406-1-ND	LED Yellow Clear 1206 SMD
□ D401	Yellow	160-1406-1-ND	LED Yellow Clear 1206 SMD
□ D501	Yellow	160-1406-1-ND	LED Yellow Clear 1206 SMD
□ D601	Yellow	160-1406-1-ND	LED Yellow Clear 1206 SMD
□ D701	Yellow	160-1406-1-ND	LED Yellow Clear 1206 SMD
□ D801	Yellow	160-1406-1-ND	LED Yellow Clear 1206 SMD
□ F1		F063-ND	Clip Fuse 10A 5X20MM PC MOUNT
□ Fuse	5x20 5A	F2395-ND	Fuse 250V IEC FA LBC 5X20 5A
□ IC1	PCF8574P	568-1073-5-ND	IC Remote I/O Expander 16-DIP
□ IC101	MOC3010M	MOC3010M-ND	Optocoupler Triac-out 6-DIP
□ IC201	MOC3010M	MOC3010M-ND	Optocoupler Triac-out 6-DIP
□ IC301	MOC3010M	MOC3010M-ND	Optocoupler Triac-out 6-DIP
□ IC401	MOC3010M	MOC3010M-ND	Optocoupler Triac-out 6-DIP
□ IC501	MOC3010M	MOC3010M-ND	Optocoupler Triac-out 6-DIP
□ IC601	MOC3010M	MOC3010M-ND	Optocoupler Triac-out 6-DIP



I/O Board Parts List continued ...

ITEM	VALUE	PART NO.	DESCRIPTION
□ IC701	MOC3010M	MOC3010M-ND	Optocoupler Triac-out 6-DIP
□ IC801	MOC3010M	MOC3010M-ND	Optocoupler Triac-out 6-DIP
□ Q201	Q4008LH4SHORT	Q4008LH4-ND	Alternistor 400V 8A TO-220AB
□ Q301	Q4008LH4SHORT	Q4008LH4-ND	Alternistor 400V 8A TO-220AB
□ Q401	Q4008LH4SHORT	Q4008LH4-ND	Alternistor 400V 8A TO-220AB
□ Q501	Q4008LH4SHORT	Q4008LH4-ND	Alternistor 400V 8A TO-220AB
□ Q601	Q4008LH4SHORT	Q4008LH4-ND	Alternistor 400V 8A TO-220AB
□ Q701	Q4008LH4SHORT	Q4008LH4-ND	Alternistor 400V 8A TO-220AB
□ Q801	Q4008LH4SHORT	Q4008LH4-ND	Alternistor 400V 8A TO-220AB
□ R1	1K	P1.00KFCT-ND	RES 100Ω 1/4W 1% 1206 SMD
□ R2	10K	P10.0KFCT-ND	RES 10.0K 1/4W 1% 1206 SMD
□ R3	10K	P10.0KFCT-ND	RES 10.0K 1/4W 1% 1206 SMD
□ R4	10K	P10.0KFCT-ND	RES 10.0K 1/4W 1% 1206 SMD
□ R5	10K	P10.0KFCT-ND	RES 10.0K 1/4W 1% 1206 SMD
□ R6	10K	P10.0KFCT-ND	RES 10.0K 1/4W 1% 1206 SMD
□ R7,R8,R9,R10		Not Used	
□ R101	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R102	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R103	330R	P330BBCT-ND	RES 330Ω CARBON FILM 1/2W 5%
□ R201	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R202	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R203	330R	P330BBCT-ND	RES 330Ω CARBON FILM 1/2W 5%
□ R301	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R302	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R303	330R	P330BBCT-ND	RES 330Ω CARBON FILM 1/2W 5%
□ R401	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R402	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R403	330R	P330BBCT-ND	RES 330Ω CARBON FILM 1/2W 5%
□ R501	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R502	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R503	330R	P330BBCT-ND	RES 330Ω CARBON FILM 1/2W 5%
□ R601	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R602	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R603	330R	P330BBCT-ND	RES 330Ω CARBON FILM 1/2W 5%
□ R701	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R702	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R703	330R	P330BBCT-ND	RES 330Ω CARBON FILM 1/2W 5%
□ R801	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R802	475R	P475FCT-ND	RES 475Ω 1/4W 1% 1206 SMD
□ R803	330R	P330BBCT-ND	RES 330Ω CARBON FILM 1/2W 5%
□ S1	DIP Switch 3POS	GH7182-ND	DIP Switch Extended Sealed 3POS

Note: All part numbers are Digi-Key part numbers unless noted otherwise.

the encoder movements, and a quick check of all segments is suggested. Note that depending upon the mounting of

the card, the LED display may be upside-down. There are two look-up tables and a notation in the firmware, which inverts

the data and swaps the digits to correct the inverted display.

Once an I/O card is completed and inspected, it can be connected to the controller card with a 10 pin ribbon cable. Additional I/O cards are daisy-chained through the same ribbon cable and a second connector on either the controller card or the I/O cards. Each I/O card needs a unique base address, which is set with a three position DIP switch. More than one I/O card can have the same address – in which case, the I/O cards will each replicate the same sequence.

The green LED on each I/O card indicates 5V power is present, and the controller sends I²C data to the I/O card to activate the output channels. With the test software, the eight channels can be stepped by using the rotary encoder (on the controller card), and confirmed with the yellow LEDs (one per channel).

The final stage of the I/O card check-out is to apply AC power and a test lamp (or multiple lamps). I constructed eight lamp sockets on an acrylic strip to hold eight C7-1/2 5W bulbs. This is actually a luxury that isn't required for testing. This can be done with a single 120V 'type A' 40W household bulb and suitable holder on a length of lamp cord wire. Again, take care not to touch the live PCB!

Once the cards are checked out on the bench, they can be installed and wired up within the cabinet.

Firmware Installation

As noted in the introduction, the holiday lights controller operates without connection to a PC or other devices. The upside is that a PC is not tied up for the project, but the downside is that programming of the holiday lights controller is required in the first place. The initial idea was to program the AVR chip, which can be done off-line (with a suitable AVR programmer connected to a PC). This is still the simple way to go!

Another tool is the AVR ISP port that allows the µC to be erased and reprogrammed in circuit. As a practical matter, it's not easy to haul the system back to the workshop each time, so the

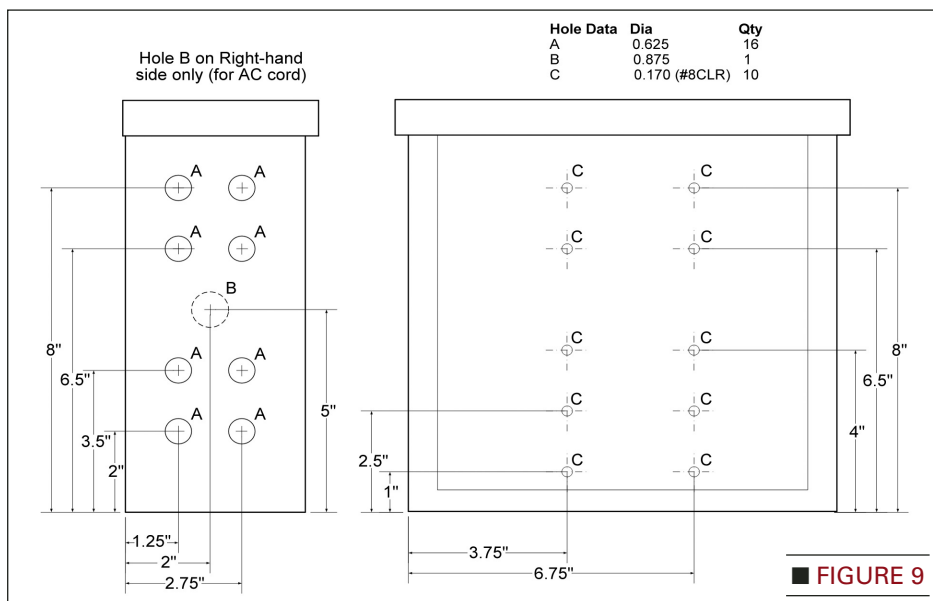


FIGURE 9

fall-back position is to exchange the AVR chip (which has a socket).

Another feature of the holiday lights controller is the pattern sequences stored in the EEPROM. It's easier to replace this eight pin DIP rather than the larger AVR! Options are left to the user.

Firmware Operation

The next challenge is to see how the controller behaves in use. There are three distinct modes: RTC control, light show control, and manual control.

RTC control refers to the automatic turn on/turn off of the light show using the data in the firmware (start time and stop time) and the RTC time. These set points can be accessed from the controller (with the optional LCD module attached).

Once the light show starts, the μC is used to control the lights, which continues until the firmware detects the stop time. Finally, we need a way to turn the light show on and off manually, tweak the start and stop times, and select light show patterns that

have been pre-programmed.

Light Show (Version 1)

The current operating firmware is called "light show version 1," and it makes full use of the RTC start and stop timers and has many fixed patterns. I used this system last season, and have since developed new sequences. This is an area that will probably interest other people who may want to build on light show version 1 and create something more interesting!

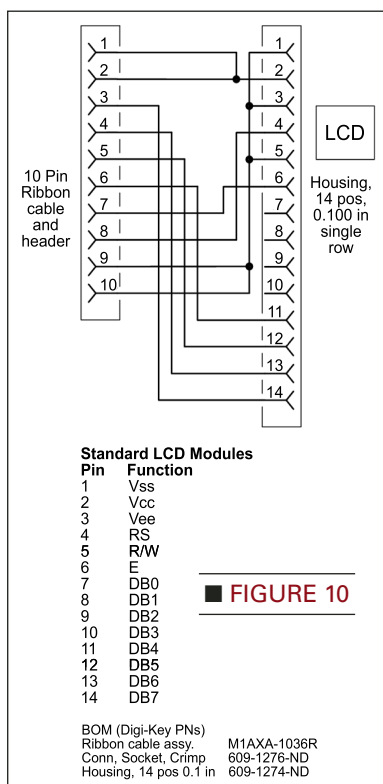
Any Suggestions?

Since building the prototype, I have developed some interesting patterns and sequences. These are also available for download from the *Nuts & Volts* website.

Anyone that has a neat idea for a sequence or light show (using the hardware described here) is welcome to contact the author (and we can share these). Also, I can provide bare, professionally made PCBs (and assembled PCBs) for a nominal cost; just send me an email at pstonard@ix.netcom.com. **NV**

CONTROLLER BOARD PARTS LIST

Item	VALUE	PART NO.	DESCRIPTION
<input type="checkbox"/> B1	Coin_Cell_HDR_10 mm	BH401	Holder Battery for 10 mm cell
<input type="checkbox"/> Battery	CR1025	N031-ND	Battery Lithium Coin 3 volt 10 mm
<input type="checkbox"/> BR1	2KBP01	2KBP01M/1GI-ND	Rectifier Bridge 2A 100V KBPM
<input type="checkbox"/> C1	8200/16V	P10266-ND	CAP 8200 μF 16V Elect FC Radial
<input type="checkbox"/> C2	10 μF /16V	ECE-A1CKA100	CAP 47 μF 35V Alum Lytic Radial
<input type="checkbox"/> C3	4.5-20 pF	GKG20066	CAP 4 x 4.5 mm 4.5-20 pF Top Adj SMD
<input type="checkbox"/> CN1	OSTTB06	ED2574-ND	Terminal Block 5 mm HOR 6Pos PCB
<input type="checkbox"/> CN2	OSTTB03	ED2571-ND	Terminal Block 5 mm HOR 3Pos PCB
<input type="checkbox"/> CN3	OSTTB06	ED2574-ND	Terminal Block 5 mm HOR 6Pos PCB
<input type="checkbox"/> CN4	HDR2X5	A26573-ND	Conn Header Vert .100 10Pos 15AU
<input type="checkbox"/> CN5	HDR2X5	A26573-ND	Conn Header Vert .100 10Pos 15AU
<input type="checkbox"/> CN6	HDR2X5	A26573-ND	Conn Header Vert .100 10Pos 15AU
<input type="checkbox"/> CN7	HDR2X5	A26573-ND	Conn Header Vert .100 10Pos 15AU
<input type="checkbox"/> D1	RL201	RL201-TP	Diode STD Rec 2A 50V DO15
<input type="checkbox"/> DS1	LDD-E304NI	67-1409-ND	LED 7-Ses .30 Dual Red CA Multix
<input type="checkbox"/> F1		F063-ND	Clip Fuse 10A 5 x 20 mm PC Mount
<input type="checkbox"/> Fuse	5x20 5A	F2395-ND	Fuse 250V IEC FA LBC 5 x 20 5A
<input type="checkbox"/> IC1	L7805	497-1443-5-ND	IC Positive Reg 5V TO-220FP
<input type="checkbox"/> IC2	DS1307DIL	DS1307+-ND	IC RTC Serial 512K 8-DIP
<input type="checkbox"/> IC3	24LC02BDIL	24LC02B/P-ND	IC Serial EEPROM 2K 2.5V 8-DIP
<input type="checkbox"/> IC4	MEGA8P	ED3108-ND	IC AVR MCU 8K 16 MHz COM 28-DIP
<input type="checkbox"/> LED1	RED	ED90054-ND	IC Socket 28 pin MSTIN/TIN .300
<input type="checkbox"/> Q1	MMBT4403	160-1405-1-ND	LED Super Red Clear 1206 SMD
<input type="checkbox"/> Q2	MMBT4403	MMBT4403FSCT-ND	Transistor GP PNP AMP SOT-23
<input type="checkbox"/> R1	10K	MMBT4403FSCT-ND	Transistor GP PNP AMP SOT-23
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<input type="checkbox"/> R3	10K	P10.0KFCT-ND	RES 10.0K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R4	221R	P10.0KFCT-ND	RES 10.0K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R5	221R	P221FCT-ND	RES 221 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R6	221R	P221FCT-ND	RES 221 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R7	221R	P221FCT-ND	RES 221 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R8	221R	P221FCT-ND	RES 221 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R9	100R	P221FCT-ND	RES 221 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R10	100R	P100FCT-ND	RES 100 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R11	10K	P100FCT-ND	RES 100 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R12	10K	P10.0KFCT-ND	RES 10.0K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R13	1K0	P10.0KFCT-ND	RES 10.0K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R14	332R	P1.00KFCT-ND	RES 1.00K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R15	332R	P332FCT-ND	RES 332 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R16	10K	P332FCT-ND	RES 332 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R17	221R	P10.0KFCT-ND	RES 10.0K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R18	221R	P221FCT-ND	RES 221 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R19	3K92	P221FCT-ND	RES 221 Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R20	1K0	P3.92KFCT-ND	RES 3.92K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R21	1K0	P1.00KFCT-ND	RES 1.00K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R22	3K92	P3.92KFCT-ND	RES 3.92K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R23	10K	P10.0KFCT-ND	RES 10.0K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> R24	10K	P10.0KFCT-ND	RES 10.0K Ohm 1/4W 1% 1206 SMD
<input type="checkbox"/> S1	ENCODER	CT3000-ND	ROT Encoder 2 bit BIN W/SW HORZ
<input type="checkbox"/> S2		CKN9098-ND	Switch Tact 6 mm SPST H = 4.3 mm
<input type="checkbox"/> T1	3FD-516	MT2108-ND	Transformer Dual 8 VAC 1.6A
<input type="checkbox"/> X1	32 kHz	300-8305-1-ND	Crystal 32.768 kHz SMD 12.5 pF



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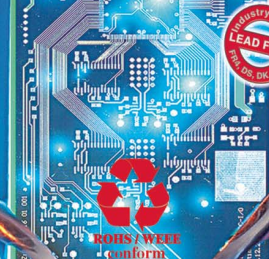
Easy-PC

BOYD

GraphiCode

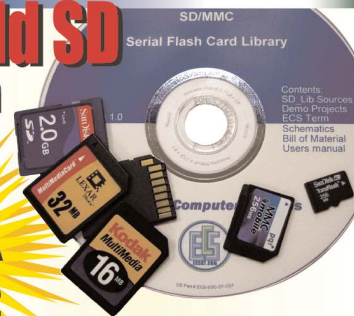
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Flash Card Adapter Board

The flash card adapter board contains all the basic circuitry needed to add PC-compatible flash card memory to virtually any microcontroller application, using as few as four I/O pins. It includes a 3.3V regulator, built-in level shifting, and sockets for both SD/MMC and MicroSD/TransFlash memory cards.



Development Board

The development board includes a built-in demo application and all the necessary hardware to run each of the example programs included with the SFCLIB (sold separately). It includes sockets for SD/MMC and MicroSD/TransFlash memory cards.



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FOR PCBs

by Mike Allan and Steven Huang

Thermal modeling printed circuit boards (PCBs) in high power density applications is a critical part of circuit design. With more discrete components condensed on smaller PCBs, heat flow starts to play a big role. After all, consumers don't want to have laptops burning their thighs or desktops exuding the nauseous fumes of plastic. Much thought, analysis, and testing are put into electronic designs to properly cool and dissipate heat. As a rule of thumb, the more analysis and testing that is needed, the more resources, time, and money are needed.

But here at Po'Man's, our motto is "Why pay big bucks for expensive tools, when there might be a cheap way to get the job done?" One of our favorite inexpensive tools is LTSpice [1], which comes with an integrated schematic capture tool that allows hierarchical schematics, cross probing of nets, and more options you can explore in a month. It is great for lots of quick engineering checks and preliminary design ideas. The basic computation engine allows a lot of other problems to be solved as well, not just standard circuits.

It turns out Spice-based engines lend themselves readily to modeling simple thermal flow of a board. Heat transfer can be modeled as a direct analog to Ohm's Law. Temperature rise can be viewed as a voltage source, dissipated power [W] can be viewed as current, and electrical resistance as thermal resistance [°C/W].

EQUATION 1:

$$T_{rise}[^{\circ}C] = P[W] * R_{therm}[^{\circ}C/W]$$

The power dissipated by the copper (Cu) in the board generates the temperature within a PCB due to its resistivity. You can derive the power dissipated through a board from the DC resistance of a copper plane. In general, the longer a copper plane/trace, the more DC resistance exists, and the

more surface area of the copper plane/trace, the less DC resistance exists. A simple estimation is:

EQUATION 2:

$$R_{D.C.}[\Omega] = \frac{\tilde{n}[\Omega * cm] * L[cm]}{A[cm^2]}$$

From Equation 2, the power dissipated is calculated:

EQUATION 3:

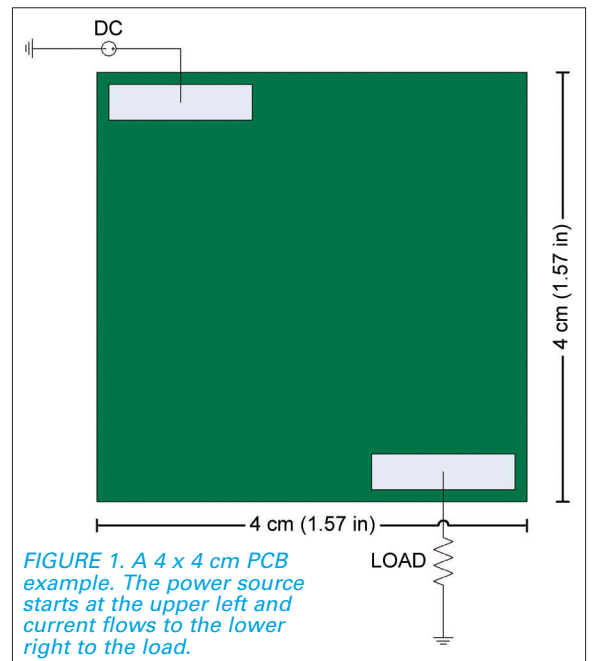
$$P_{diss}[W] = I^2[A^2] * R_{D.C.}[\Omega]$$

Once you know the power dissipation, you can plug it into Equation 1 and obtain the temperature rise.

Square Method

Here's an example of a 4 x 4 cm (1.57 x 1.57 inch) PCB, where a 12V voltage source starts at the top-left and flows towards the bottom right (Figure 1). To model such physical boards, a square method can be used. We divide the board into a mosaic of 1 cm x 1 cm squares, which allow reasonable approximation of the irregular board shapes, as well.

The first task is to build the resistive model using the squares. We



choose to model 0.5 oz Cu and divide the resistance of a 1 cm tile by the number of equivalent 0.5 oz layers. So, 2.5 oz total Cu for power distribution can be modeled as five resistive tiles in parallel. After a little math, we came up with 1 mW across a 1 cm 0.5 oz square. Then, we model this as four 0.1 mW resistors in an orthogonal cross, with a terminal on the left, right, top, and bottom sides (see Figure 2). The square model includes 100 megohm resistors to ground from all terminals to allow the model to

converge without adding external components.

The symbol created can be placed and repeated to create the 4 x 4 cm shape in a short amount of time. All that remains is to add an input voltage source connected to multiple squares to model the power source placement (e.g., a hot IC, power connector, etc.). The model runs in about a second, and you can then probe the voltage's point in the grid (see Figure 3). Note that the mesh structure allows you to model the multiple connection points.

Thermal Modeling

The next phase is to model the thermal flow at each square. For each square, we can think of heat flowing along the PCB (horizontally) or vertically through the stack-up. We need to model the thermal resistance in both directions. In the vertical direction, heat flows through layers of copper and dielectric material. Generally, these materials differ in their thermal resistance by about a factor of 1,000.

Interestingly, the vertical thermal resistance of the thin Cu can be neglected because it was so low, and the horizontal thermal resistance of the PCB material can be neglected because it was so high compared to the Cu [2]. As it turns out, the vertical thermal resistance of the PCB material is in the same order of magnitude as the horizontal thermal resistance of the Cu layer, so both come into play when dissipating heat near high power density regions. Based on this premise, we calculate the vertical and horizontal thermal conductivity using Azar and Graebner's equations [2]. For horizontal thermal conductivity:

EQUATION 4:

$$\kappa_{||} = 385 \cdot \frac{Tk_{Cu}}{Tk_{PCB}} + 0.87$$

where Tk_{Cu} is the total thickness of copper and Tk_{PCB} is the total thickness of dielectric in a stackup.

For vertical thermal conductivity:

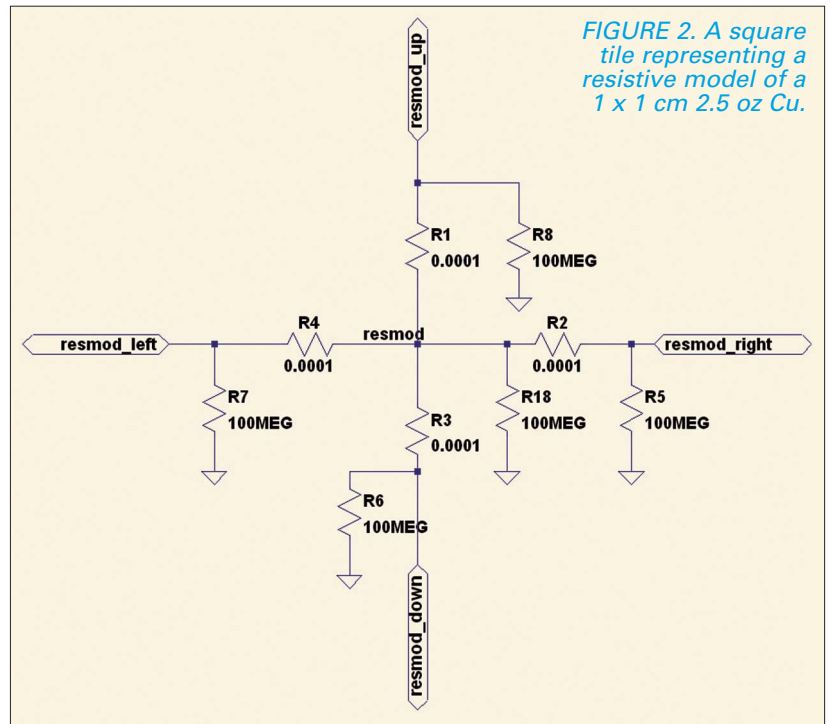


FIGURE 2. A square tile representing a resistive model of a 1 x 1 cm 2.5 oz Cu.

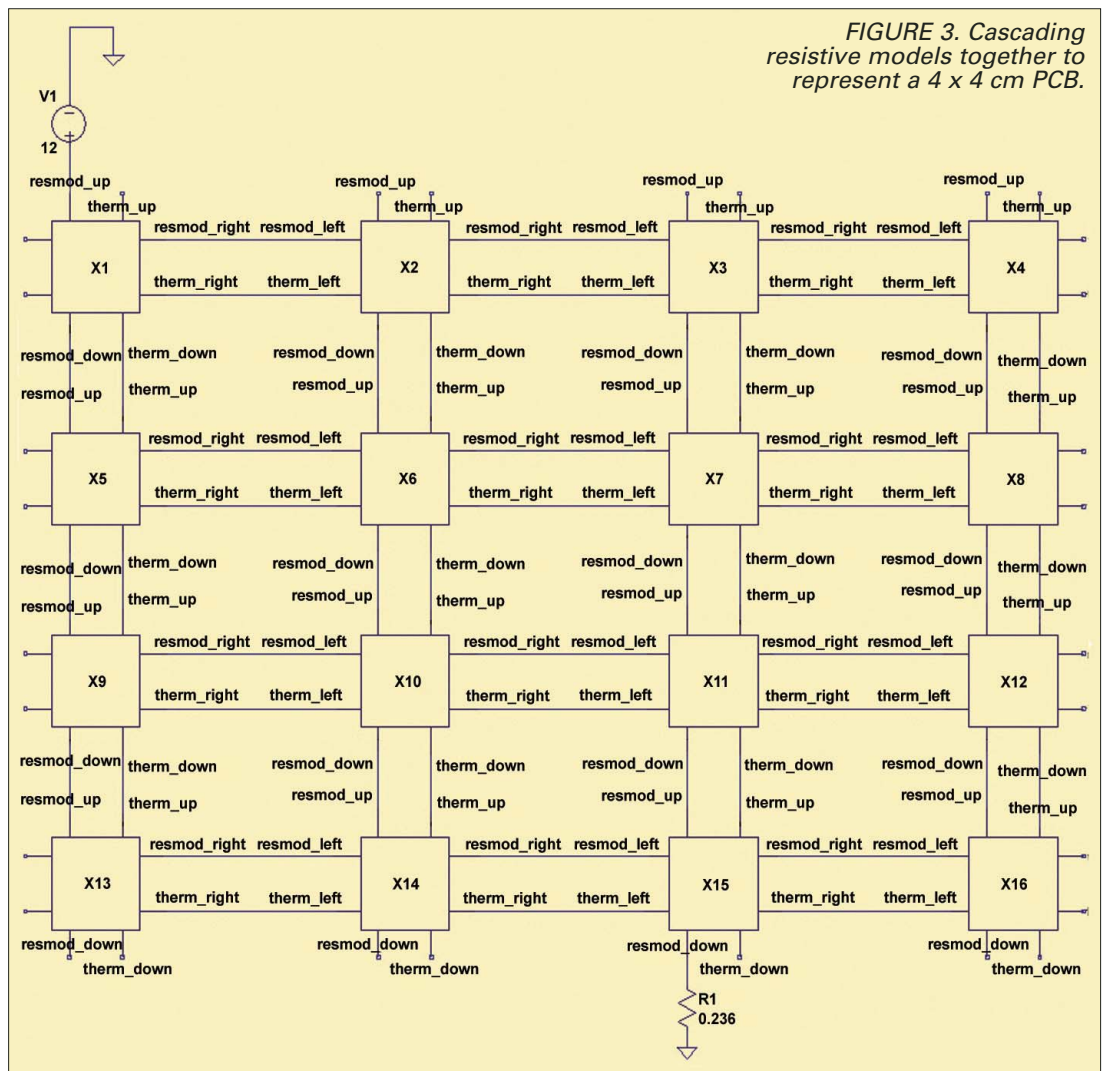
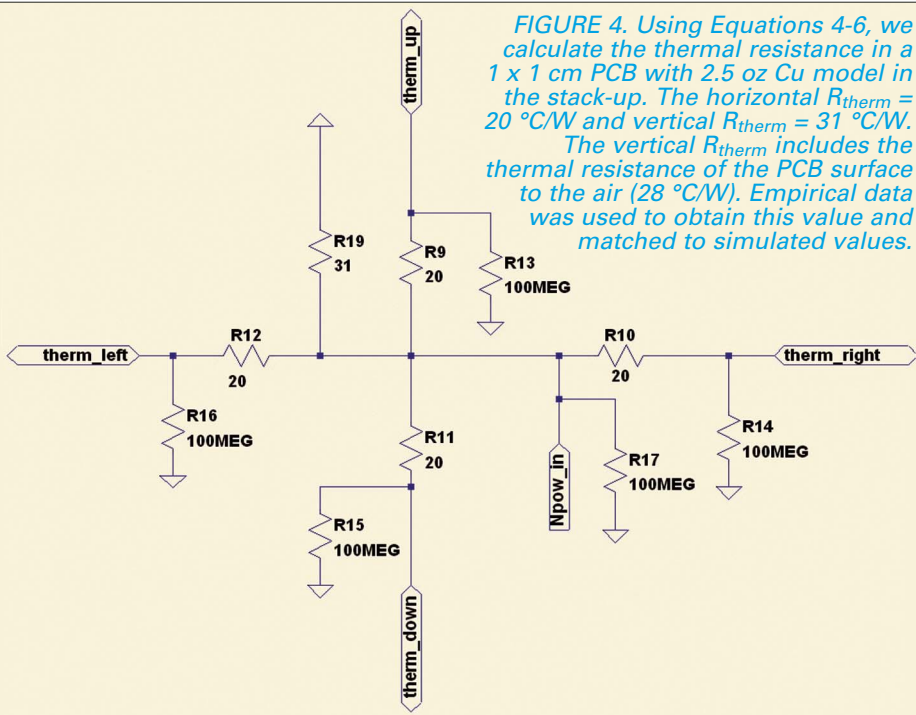


FIGURE 3. Cascading resistive models together to represent a 4 x 4 cm PCB.



EQUATION 5:

$$\kappa_{\perp} = \left(3.23 \cdot \left(1 - \frac{Tk_{CU}}{Tk_{PCB}} \right) + 0.0026 \cdot \frac{Tk_{CU}}{Tk_{PCB}} \right)^{-1}$$

The thermal resistivity is calculated by:

EQUATION 6:

$$R_{therm} = \frac{l}{SA \cdot \kappa}$$

Similar to the resistive square model, a thermal resistance square model is applied using LTSpice. The thermal resistances are plugged into the model as shown in Figure 4, and a current source is used to inject the analog to the power dissipated in the electrical square, where mA equals mW, ohms correspond to thermal resistance [$^{\circ}\text{C/W}$], and voltage corresponds to temperature. We use a dependent current source where the

References

[1] LTSpice/SwCad III. www.linear.com/designtools/software.
 [2] Azar, K. and Graebner, J.E. "Experimental Determination of Thermal Printed Wiring Boards." IEEE Semi-Therm Symposium. 1996.

power from all resistors (Equation 3) is fed into the thermal square model. Then, we simulate the model and are able to probe the voltage points which correspond to temperate rise.

Results/Conclusion

With a 50A current source, the simulation models a temperature rise of 10-11 $^{\circ}\text{C}$ near the current source. As the heat spreads through the board, the heat dissipates, dropping to 3-4 $^{\circ}\text{C}$ at the right edge. This is a very comforting number and we'll take it! Depending on your design, the results can help determine parameters like stack-up, board area, and copper size.

Our simulations by no means replace costly analysis tools as the model makes basic approximations about the thermal resistivity and neglects other parameters like air flow (e.g., fans) and vias. While the model doesn't use fancy dynamic models, you can create and model arbitrary size boards and different loads. With the added advantage, you can do this quick analysis for free. **NV**

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A Brief SPICE Background

SPICE (Simulation Program with Integrated Circuit Emphasis) is a powerful, general-purpose circuit simulator used for predicting and verifying circuit designs. Developed at the Electronics Research laboratory of UC-Berkeley, SPICE1 was released in 1973. Over the years, SPICE has undergone improvements moving from FORTRAN to C and adding support for more analysis modes like noise, Monte Carlo, Fourier, etc.

More importantly, since SPICE was an open source program, many SPICE-based variants have proliferated. There are commercial versions like PSPICE, HPSPICE, and best of all, there are free versions (e.g., LTSPICE, TINA-TI). Many board-level and IC designers have adopted some form of SPICE-based simulators as a way to reduce design cycles, mitigate risk, increase quality, and save money. Today, SPICE-based simulation programs are an industry standard tool for design.



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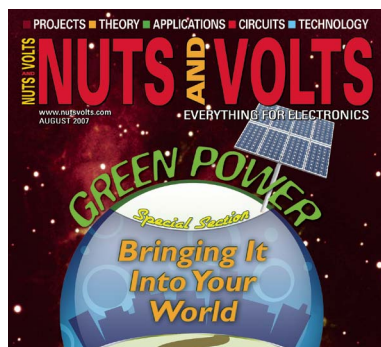
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Lattice Wave

DIGITAL FILTERS

by Craig Lindley

There has been a lot written about the design and implementation of digital filters over the years and I periodically survey the literature to try and keep up with it. It seemed the right time to look around again when I decided to build a digital color organ [1] which would require digital filtering. During this latest survey, I came upon Lattice Wave Digital Filters (LWDFs) which I was not familiar with. These filters piqued my interest as they had intriguing properties directly applicable to my application.

Typically, when I find a technology that interests me, I go overboard in my research and spend lots of hours playing with it in order to understand it. LWDFs were no exception. This article, and the accompanying design tool, were a result of my investigation into LWDFs which were just too cool to pass up. We will get to LWDFs shortly, but first a little context.

There exists two major classes of digital filters referred to as Infinite Impulse Response (IIR) — sometimes called a recursive filter — and Finite Impulse Response (FIR) or convolution filters. Both of these filter types have advantages and disadvantages which make them each suitable for a variety of applications.

IIR filters might be used, for example, in applications where cost is a concern because they can be implemented using a minimum of hardware/software resources. FIR filters would be used in applications where linear phase response is required such as in high end audio applications, the processing of sensor data, or possibly radio telescope data. FIR filters use more resources to implement to the same order as an equivalent IIR filter.

Typically, IIR filters are not as stable as their FIR counterparts. This fact is reflected in their names. Infinite Impulse Response filters will typically ring for a period of time after being subjected to an impulse waveform. Finite Impulse Response filters are better damped and any ringing of the filter will be of much shorter duration.

IIR filters also have sensitivity to word length limitations and coefficient round off errors which makes their implementation tricky. All this is to say that testing is very important for any digital filter you design (regardless of topology) to make sure it is performing per your requirements.

IIR filters were appropriate for the application I had in mind because of their inherent efficiencies, but only if their stability issues could be controlled or eliminated. This is where LWDFs came into play.

All of the information I found on these filters indicated they were extremely stable, had a large dynamic range, and weren't sensitive to either limited word lengths or round off errors. LWDFs don't correct the erratic phase response of classic IIR filters but phase response is not important in my application.

LWDFs were first proposed by Professor Alfred Fettweis in 1971 and are backed with an extensive amount of complex network theory which one does not need to understand to apply. A lot of information can be found on the Internet describing these filters. The Resources sidebar details some of the most useful papers I found. Specifically, the TI application note and the paper by Gazsi were the most helpful to me and my understanding of this technology.

LWDFs are a cascade of first and second order all pass filter sections. Each all pass section is made up of a two port adapter (picture a little box with two inputs in1 and in2 and two outputs out1 and out2) along with a one sample delay element. Every adapter has a gamma value (gamma values range in value between -1 and +1) which controls the response of the all pass section. Adapters are implemented in software using a set of network formulas which require a single multiplication and three additions each.

The LWDFs we are discussing use four types of adapters as filter building blocks. The number and the variety of adapters used along with the gamma

values associated with each are typically generated using some sort of filter design tool. (More on filter design tools shortly.)

Even though the gamma value controls the response of the all pass sections, we don't typically deal directly with gamma in an implementation. Instead, alpha values in the range 0 to 0.5 are used as multipliers because they are easier to use and implement. Each of the four adapter varieties uses a different method of converting gamma into alpha. This is illustrated in Table 1.

Low pass, band pass, band reject, and high pass filters of Butterworth, Chebyshev, and Cauer Parameter (Elliptic) forms can be built using the adapter building block approach. Actually, only low and high pass filters are directly implemented. Band pass and band reject filters are produced by cascading high pass and low pass filters together.

Note that only odd order (first order, third order, fifth order, etc.) filters can be designed using these techniques. Note also that there is a one-to-one ratio between filter order and the number of adapters necessary to achieve it. Three adapters will be required for a third order filter, for example.

Adapters and delays are connected together using a standard topology to form LWDFs. The standard topology is shown in Figure 1.

The single sample delay associated with each adapter records the previous output of the adapter. The previous output is used in conjunction with the current input and gamma/alpha value to produce a new output from the adapter. All adapters working together form the LWDF.

As also shown in Figure 1, the filter's response is determined by how the final top and bottom adapter output are combined. If the top and bottom outputs are summed and divided by two, the result is the low pass response. If the bottom output is subtracted from the top output and

Adapter Type	Gamma Range	Gamma/Alpha Conversion	2 Port Network Formulas
Type 1	$0.5 < \gamma < 1.0$	$\alpha = 1 - \gamma$	$p = in1 - in2$ $out2 = \alpha * p + in2$ $out1 = out2 - p$
Type 2	$0.0 < \gamma \leq 0.5$	$\alpha = \gamma$	$p = in2 - in1$ $out2 = \alpha * p + in1$ $out1 = \alpha * p + in2$
Type 3	$-0.5 \leq \gamma < 0.0$	$\alpha = \gamma $	$p = in1 - in2$ $out2 = \alpha * p - in1$ $out1 = \alpha * p - in2$
Type 4	$-1.0 < \gamma < -0.5$	$\alpha = 1 + \gamma$	$p = in2 - in1$ $out2 = \alpha * p - in2$ $out1 = out2 - p$

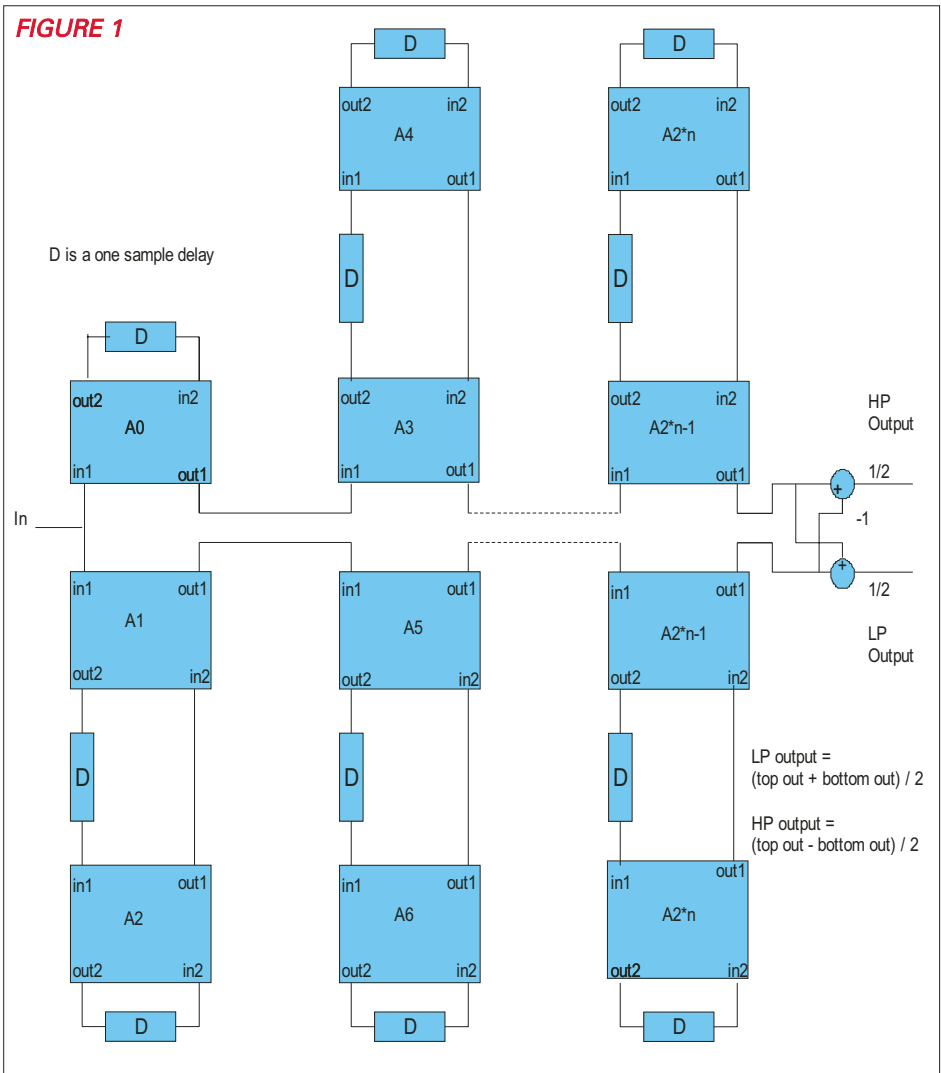
TABLE 1

divided by two, the result is a high pass filter.

Band pass and band reject (also called band stop or notch) filters are built by cascading a high pass LWDF and a low pass LWDF, in that order. If the low pass output is used from the final low pass filter, a band pass filter

results. If the high pass output of the low pass filter is used instead, a band reject filter results. Of course, it is necessary to design the high and low pass filters correctly to get the band pass or band reject response you desire.

The order in which adapters are



Listing 1

```
/**
 * Listing One - Java implementation of Low
 * Pass Lattice Wave Digital Filter
 *
 * Third order Chebyshev with fc ~ 125 Hz
 *
 * Adaptor 0    Type 1
 * Adaptor 1    Type 4
 * Adaptor 2    Type 1
 *
 * Adapter implementation order: 0,2,1
 * The three delays are integer values declared
 * elsewhere
 * @param sample the input sample to the filter
 *
 * @return filtered output sample
 */
public int filter(final int sample) {

    // Alpha values for Low Pass filter
    double ALPHA0 = 0.03152717358745383;
    double ALPHA1 = 0.03150520431915038;
    double ALPHA2 = 0.00141597724820163;

    // Adaptor 0 - Type 1

    int in1 = sample;
    int in2 = delay0;
    int p = in1 - in2;
    double acc = p * ALPHA0;
    int out2 = (int) acc + in2;
    delay0 = out2;
    int out1 = out2 - p;
    int topOutput = out1;

    // Adaptor 2 - Type 1

    in1 = delay1;
    in2 = delay2;
    p = in1 - in2;
    acc = p * ALPHA2;
    out2 = (int) acc + in2;
    delay2 = out2;
    out1 = out2 - p;

    // Adaptor 1 - Type 4

    in1 = sample;
    in2 = out1;
    p = in2 - in1;
    acc = p * ALPHA1;
    out2 = (int) acc - in2;
    delay1 = out2;
    out1 = out2 - p;
    int bottomOutput = out1;

    // Combine outputs
    return ((topOutput + bottomOutput) / 2);
}
```

executed is very important to the stability of the resulting LWDF. It is important to execute all of the top adaptors (A0, A3, A4, etc.) before

- Type: Chebyshev Low Pass
- Passband edge frequency: 125
- Stopband edge frequency: 250
- Passband ripple (dB): 0.5

Adapter Number	Adapter Type	Gamma Value	Alpha Value
0	1	0.9684728264125462	0.03152717358745383
1	4	-0.9684947956808496	0.03150520431915038
2	1	0.9985840227517984	0.00141597724820163

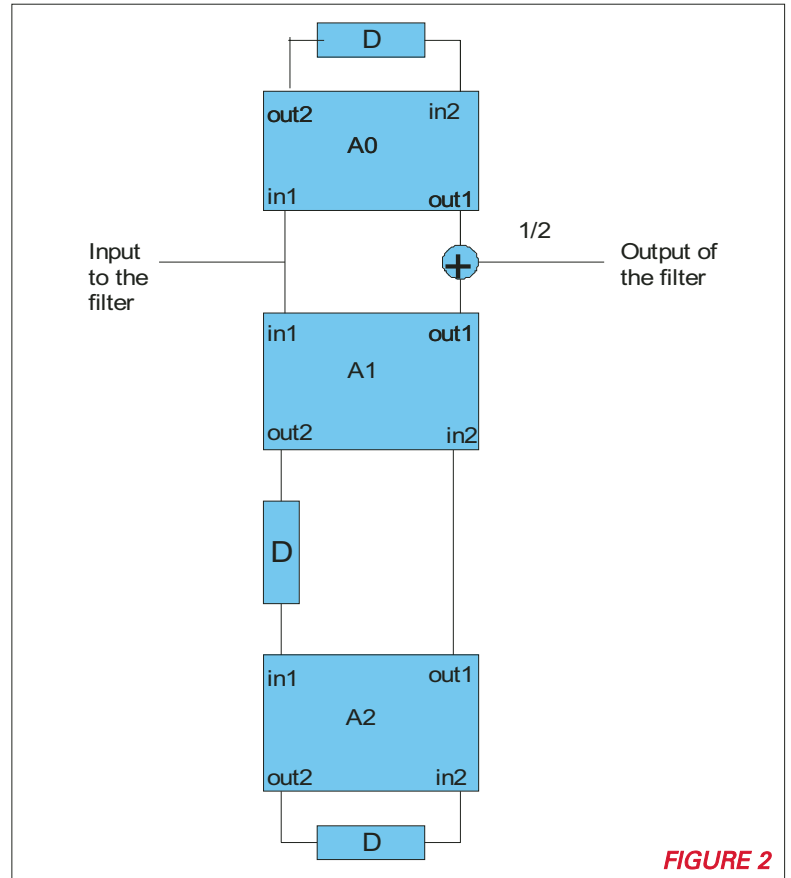


FIGURE 2

executing the bottom adaptors (A1, A2, A5, A6, etc.). Also, the adaptors must be executed from the outside in. That is, A2 is executed before A1, A4 before A3, etc. The following example illustrates this.

LWDF Design Example

Suppose we want to design a filter with the following characteristics:

- Sample rate: 16,000 samples/second

- Stopband attenuation (dB): 18

Running these specifications through an LWDF design tool tells us that the resulting filter will be third order. Figure 2 shows us what the actual filter topology looks like.

In addition to the filter's order, the LWDF design tool provides us with information about the types of adaptors to use and the gamma/alpha values associated with each. For our example filter, see Table 2.

With this information, the filter can be implemented. Listing 1 shows a Java implementation, though you could implement it in the computer language of your choice. If you fed this function a stream of appropriate digital samples, you would get a response close to what was specified.

Assembly language programmers don't get off so easy. Listing 2 shows the same filter written in MSP430F2012 assembly language. (Listing 2 is available on the Nuts &

TABLE 2

LWDF Design Tools

When I first started experimenting with LWDFs, I used a program called `wd_coeff.exe` from TI (see Resources) to generate adapter types and alpha values for the filters I needed to build. I then hand-coded the filters in MSP430 assembly language and generated a series of sine waves (internal to the processor) to validate my designs. This was a tedious process to say the least. Later, I wrote a Java program to simulate the filters with the coefficients generated by `wd_coeff.exe`. This was better, but still left a lot of room for error. Finally, I wrote a full LWDF design program called `LWDFDesigner.java` that takes a set of filter specifications like we used for our example and does the following:

- 1) Performs the LWDF calculations necessary to design the filter. `LWDFDesigner` supports Butterworth, Chebyshev, and Cauer Parameter (Elliptic) filters of low pass, band pass, band reject, and high pass varieties.
- 2) Compiles the filter design into a filter topology in memory.
- 3) Subjects the compiled filter to a stream of digital samples from 50 Hz to 50 Hz less than one half the specified sample rate, and captures the results.
- 4) Analyzes the filter's response and graphs the result.

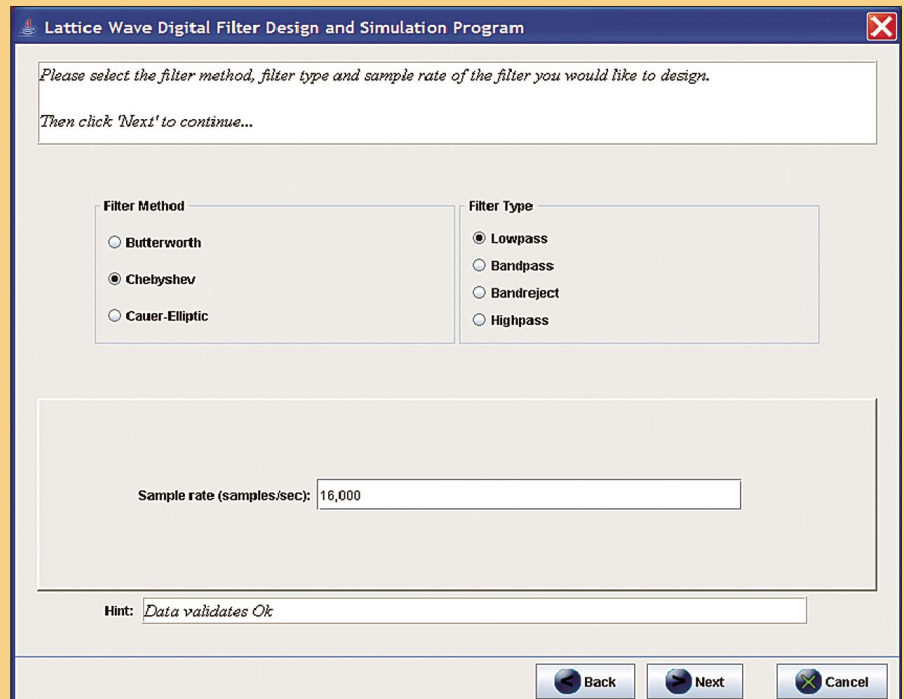
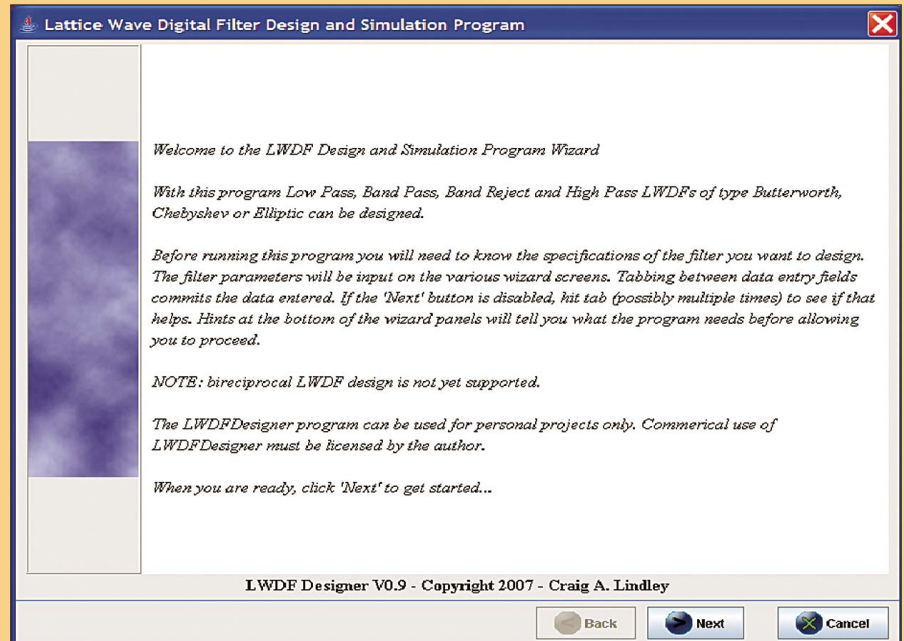
`LWDFDesigner` make LWDF design easy. The ability to see the results of filter execution immediately takes most of the guess work out of the process. `LWDFDesigner` is still a work in progress and will evolve over time. I plan on adding a plug-in to the program that will generate the MSP430 assembly code for the filters directly. As it stands now, the filters designed using `LWDFDesigner` must still be coded by hand using the information generated by the program.

Running LWDFDesigner.java

To run `LWDFDesigner.java`, you will need to have a Java Development Kit (JDK) installed on your computer. The program was written for use with Java 5 which is available for free from Sun Microsystems at http://java.sun.com/javase/downloads/index_jdk5.jsp. The newer Version 6 of Java should also work.

An executable version of the `LWDFDesigner.java` program is available from the Nuts & Volts website, and is named `LWDFDesigner.jar`. The code is meant to be run directly from the jar file using the following command line from a command shell (`cmd.exe`) in Windows XP:

```
java -jar <path to where the jar file resides>\LWDFDesigner.jar
```



continued ...

Sidebar continued ...

If this doesn't work, make sure the bin directory of the JDK installation is on the Path in your command shell. Alternately, you can change directories to the JDK bin directory and run the above command from there. LWDFDesigner does not require any command line arguments.

LWDFDesigner is written as a graphical-based wizard that guides you through the steps necessary to successfully design a filter. Each wizard page or panel validates the user entered data before allowing the user to proceed to the next page/panel. As you enter data into the program, you should tab between fields to commit and validate data. When the program is satisfied with the entered data, the 'Next' button will be enabled allowing you to move to the next page. The screenshots shown give you an idea of what to expect.

Lattice Wave Digital Filter Design and Simulation Program

Please input the parameters for the Low Pass (LP) filter you are designing. For a LP filter, the passband frequency must be less than the stopband frequency.

When you are finished click 'Next' to continue...

LP Filter Parameters

Passband edge freq (Hz): 125 Stopband edge freq (Hz): 250

Passband ripple (dB): 0.50 Stopband attenuation (dB): 18

Design Margin (0..1)

0.5

0.0 1.0

File output options

☒ Save filter data Filepath: i:\Chebyshev_Lowpass.txt

☒ Save filter graph Filepath: i:\Chebyshev_Lowpass.jpg

Hint: Data validates Ok

Back Next Cancel

Lattice Wave Digital Filter Design and Simulation Program

Chebyshev - LP filter

Low Pass Filter Component

Adapter #	Adapter Type	Gamma	Alpha
0	1	0.9684728264	0.0315271736
1	4	-0.9684947957	0.0315052043
2	1	0.9985840228	0.0014159772

Graph Filter Response

Back Finish Cancel

continued ...

The Design Cycle

I would like to tell you that by using a LWDF design tool you are able to crank out filters that match your specifications exactly every time, but I cannot. I know from implementing LWDFDesigner that inside these design programs are approximations and parameter quantizations that result in a filter that, in most cases, is close to what was specified. In fact, both the TI program and LWDFDesigner support the concept of design margin which has direct impact on the designed filter.

Design margin is a number from 0 .. 1 which determines whether the filter's stopband or the passband should be given the most effort to get right. Values towards one concentrate the design accuracy on the passband. Values towards zero concentrate on the stopband. Tweaking the design margin just a little bit changes the generated gamma values; sometimes by quite a bit.

With these facts in mind, the LWDF design cycle looks something like this:

Resources

You may find the following resources helpful:

- Java version 5 is available at: http://java.sun.com/javase/downloads/index_jdk5.jsp.
- A Texas Instruments application note discussing Lattice Wave Digital Filters is available at: http://focus.ti.com/mcu/docs/mcu_supporttechdocsc.tsp?sectionId=96&tabId=1502&abstractName=slaa331.
- Fettweis, Alfred, "Wave Digital Filters: Theory and Practice", *Proceedings of the IEEE*, Vol. 74, pp. 276-327, February 1986.
- Gazsi, Lajos, "Explicit Formulas for Lattice Wave Digital Filters", *IEEE Transactions on Circuits and Systems*, Vol. 32, No. 1, pp. 68-88, January 1985.

Footnote

[1] A color organ is a device that splits music up into numerous frequency bands and modulates colored lights (one color of light per band) according to the musical content.

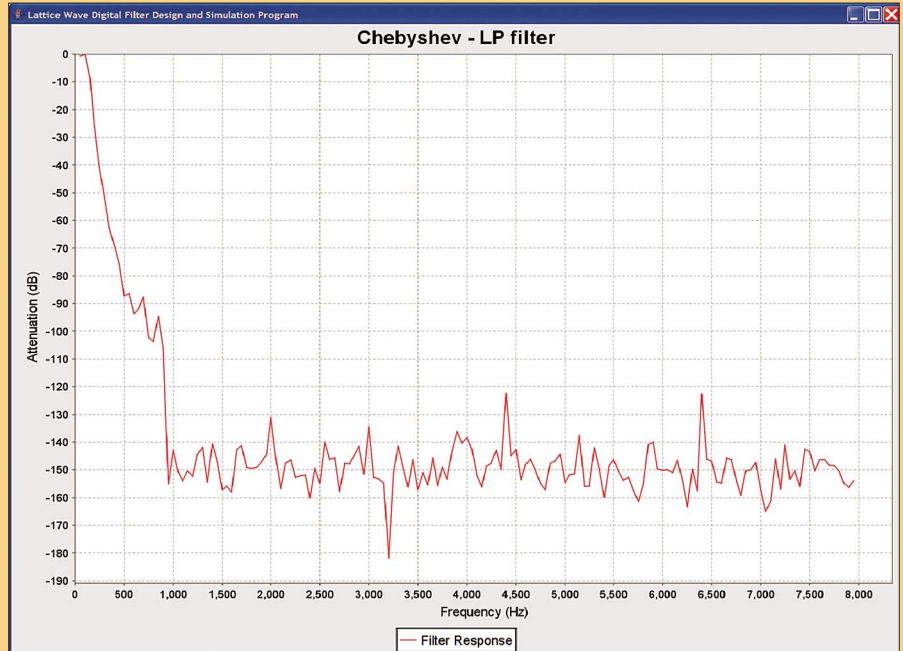
- 1) Determine the initial set of filter specifications for the filter you want to design.
- 2) Run LWDFDesigner inputting these specifications.
- 3) Graph the result to see the resulting filter response.
- 4) If the filter matches your specifications, you are done with the design phase. If not ...
- 5) Modify one or more of the filter's parameters and/or the design margin and go back to Step 2 and try again.

Once you are satisfied with the design, it is time to implement the filter. If you are a C or Java programmer, you can write code that looks like Listing 1, making sure you code the correct adapter types and gamma/alpha values produced by the design tool. Remember also it is very important to implement the top adapters first and get their execution order correct. If you are an assembly language programmer, you can take the alpha values and run them through Horner.java provided with my article in the September '07 issue to get the equations and/or the code for incorporating into your filter.

Conclusions

LWDFs are a good choice for many applications. They are easy to design, for the most part they function

Sidebar continued ...



as designed, they can be implemented in a small amount of data and code space, they use CPU cycles

sparingly, and seem to be stable. Maybe you can put them to use in your next project. **NV**

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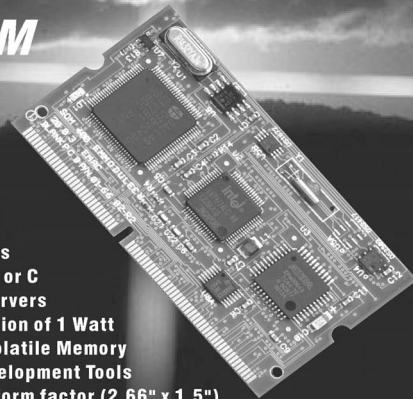
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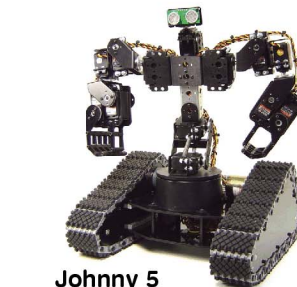
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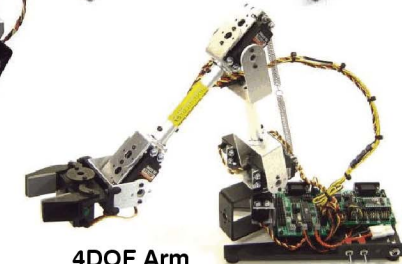
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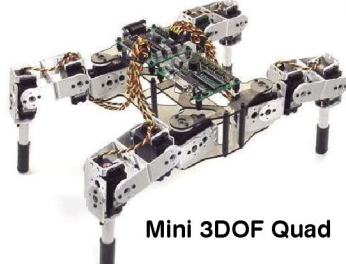
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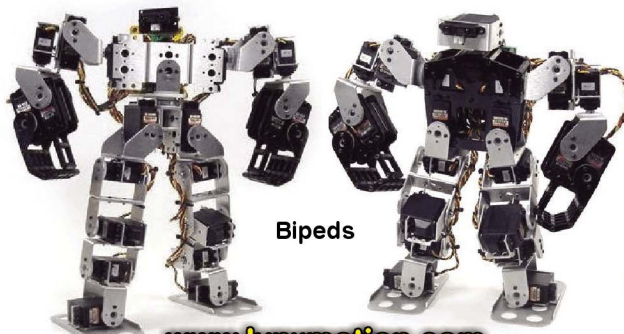
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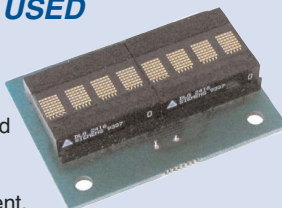
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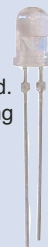
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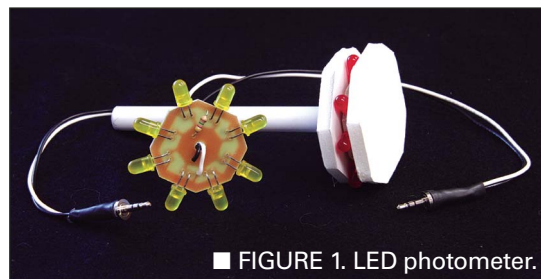
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■ BY L. PAUL VERHAGE

LED BASED PHOTOMETER

THERE'S A NEW SENSOR that I'd like to share with you this month that only requires a few LEDs and a resistor. Therefore, you probably already have everything in your junk box needed to build it. As you read in this article, you'll see that I still have a few concerns about the performance of this sensor. Even flying three of them into near space didn't answer all the questions. Oh well, that's just a reason to launch another near space mission.



■ FIGURE 1. LED photometer.

Years ago, while reading magazines in the Physics library at Kansas State University, I came across a report by Forrest Mims about using LEDs as a color specific photometer. Now a photometer is an instrument that measures the intensity of light falling on it. That sounds just like a photocell, or light sensitive resistor,

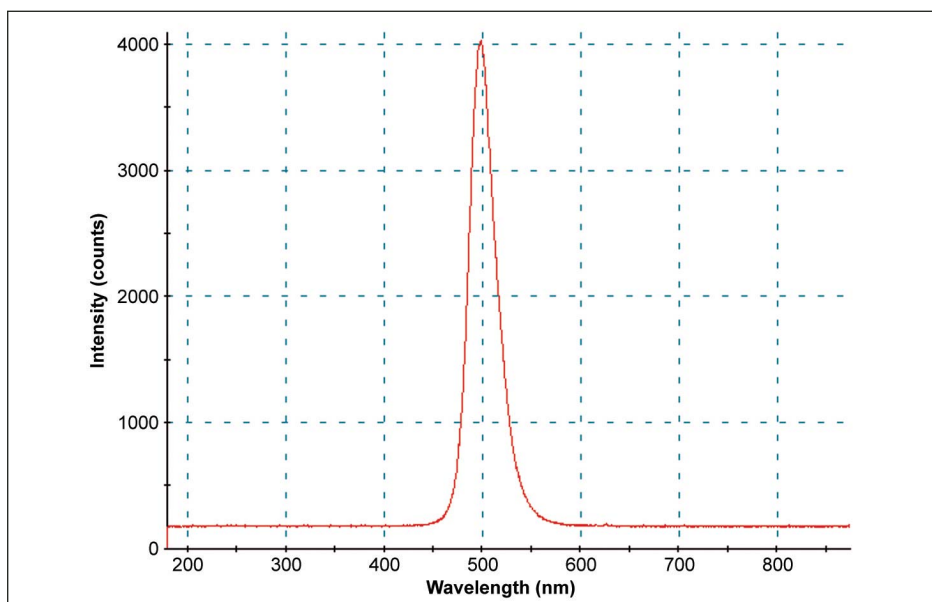
doesn't it? However, photocells are sensitive to a wide band of the spectrum, from at least infrared to the visible, while photometers are sensitive only to a narrow band of color; say, a particular shade of red. To make a photocell sensitive to a specific color, it needs a filter covering it that lets only a particular color through (these are usually expensive interference filters and not cheap colored gels). Instead of an expensive narrow band photometer or a wide

band filtered photocell, I'm using an LED to make an inexpensive medium wide band photometer.

LEDs by their nature only emit a narrow band of colors. That color is determined by the way the silicon (or in the case of blue LEDs, the gallium nitride) is cooked up. This means that unlike a traditional incandescent light bulb, the color of an LED's plastic case doesn't control its color. The color of an LED's housing merely indicates what color it will emit (and that's useful information when the LED is sitting in your junk box).

Then there's the white LED to make it a bit more complicated. White LEDs don't emit white light (which is a combination of all the colors, from red to blue, in the visible spectrum). Instead, white LEDs are blue LEDs combined with a yellow colored phosphor. So, white LEDs emit blue light and excite their phosphors to emit yellow light (which when combined, looks white to our eyes).

NOTE: All PCB patterns and files are available on the *Nuts & Volts* website at www.nutsvolts.com.



■ FIGURE 2. The emission spectrum of an LED. This chart came from the LED Museum (<http://home.att.net/~ledmuseum/>) and is from a Nichia blue-green LED. This LED — like all the others — emits a narrow band of color in the electromagnetic spectrum.

Now, what happens if you connect an LED to a circuit in reverse polarity? Well, if power is applied, nothing ... unless the voltage is greater than the peak inverse voltage (PIV) of the LED. In which case, the LED dies a horrible death (and possibly goes up in smoke). What's really neat is that you can measure a current from a reverse polarity LED because it behaves like a photodiode.

A photodiode — like a solar cell — produces a current that is proportional to the amount of light shining on it. If the intensity of the light shining on a photodiode doubles, so does the amount of current it produces. What makes an LED better at detecting light intensity than a photodiode is that LEDs are most sensitive to the color that they emit.

Since LEDs and photodiodes behave like miniature solar cells, an LED's current must be converted to a voltage if light intensity is going to be measured by an analog-to-digital converter. There are several ways to make this conversion — like a transimpedance amplifier — but I chose to use a resistor for this sensor. That's because according to Ohm's Law, the voltage drop across a resistor is equal to the resistance of the resistor times the current flowing through it. As long as the resistor value stays fixed, the voltage drop can be substituted for the LED's current and used to measure light intensity.

BUILDING THE NEARSYS LED PHOTOMETER

My first experiments with LEDs as photometers gave worthless results because during a mission, the near spacecraft constantly changed its orientation with respect to the sun. That rotation gave the resulting photometer data a lot of zigzagging. Therefore, to make the photometer less sensitive to pointing direction, the NearSys LED photometer uses eight LEDs that point

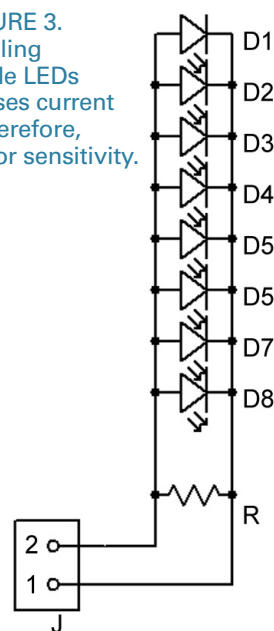
LED PHOTOMETER PARTS LIST

- Eight LEDs (all one color)
- Resistor (see note on resistor values)
- Wire
- Header for the ADC or 3/32" stereo jack for a Hobo datalogger
- NearSys LED photometer printed circuit board

outwards at 45 degree intervals. By pointing the LEDs in all directions simultaneously, the photometer should be less sensitive to its pointing direction. In addition, combining the currents from all the LEDs will make the photometer more sensitive because of the increased voltage drop across the resistor. Refer to Figure 3 for a schematic of this setup.

There's one gotcha when assembling the photometer: the LEDs must be soldered in the proper orientation. Any backward LED will block the flow of current from the other LEDs, making the photometer's output voltage zero. Notice that in Figure 4 the LEDs face outwards. As the near spacecraft rotates around its vertical axis, the combined LEDs should measure the same total light intensity around the horizon. Two wires — labeled base and tip in the top silk diagram — connect the photometer's output voltage to an ADC or Hobo datalogger. The tip is the voltage from the photometer and the base wire is the ground. My photometer cable is a foot

■ FIGURE 3. Paralleling multiple LEDs increases current and therefore, detector sensitivity.



long and terminates in a stereo jack for the Hobo.

After soldering together the photometer, I built a housing consisting of two foam core plates and a plastic shaft. When sandwiched between the foam core plates, the photometer's LEDs have a more restricted viewing angle in the vertical direction. The plates prevent sunlight from shining directly on the LEDs, thereby making the photometer even less sensitive to its pointing direction. The hollow plastic tube connected to the center of the top Styrofoam plate puts a small distance between the near

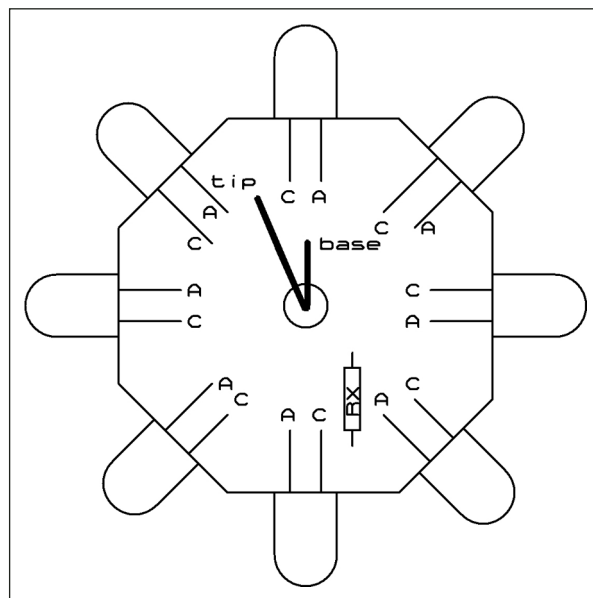
■ FIGURE 4. The placement of parts for the LED-based photometer.

RESISTOR VALUES

The voltage across the photometer's resistor depends on the intensity of the light shining on the LEDs. Here are some values I've experimented with under full sunlight. They'll be good enough to get you started.

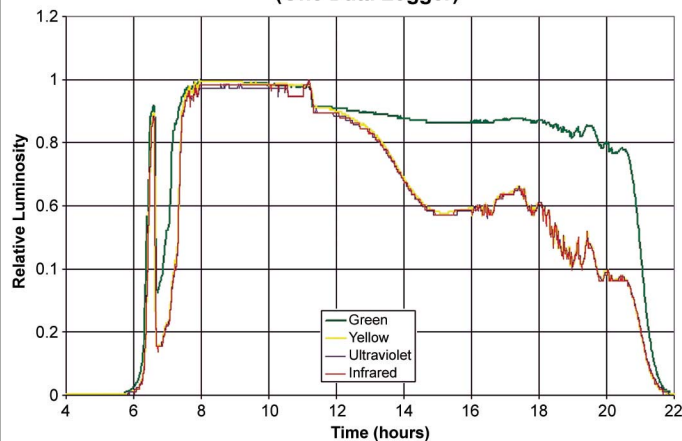
LED Color	Resistor	Voltage
Infrared	10M	0.2
Red	3.3M	1.0
Yellow	100K	1.2
Green	4.7M	1.6

Remember that a Hobo datalogger has a maximum voltage of two volts.



■ FIGURE 5

LED Photometers
(One Data Logger)



spacecraft airframe and LED photometer. The rigid plastic tube will prevent the photometer from swinging back and forth any more than the near spacecraft and it's a convenient place to run the cable through.

OUTPUT FROM THE LED-BASED PHOTOMETER

Since the output of an LED is proportional to light intensity, measuring the changes in light intensity is as simple as dividing the starting voltage across the resistor by its voltages later in the mission. Unfortunately, I have no way to determine the absolute intensity of sunlight before launch. Therefore, I can only produce charts showing the relative changes in light intensity as a function of time (and by using GPS data, as a function of altitude). The Excel formula for calcu-

lating relative intensity looks like this.

$$=X1/Y\$1$$

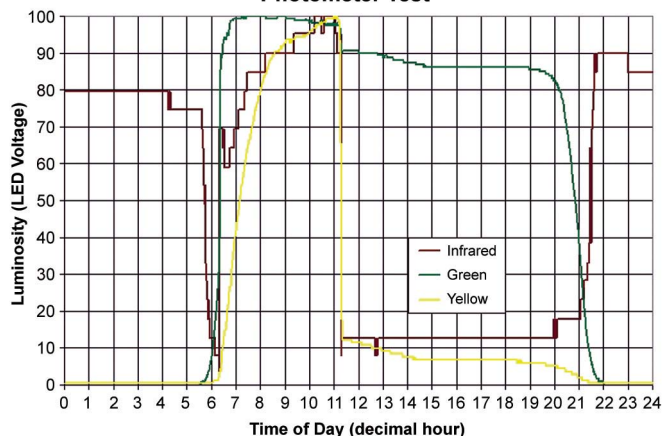
In the equation, X1 is the cell address of the ADC value loaded into the spreadsheet and Y1 is the initial light intensity value. To keep the value of Y1 fixed in the spreadsheet, its address is written as \$Y\$1.

TESTING NEARSYS LED PHOTOMETERS

It's easy to build an LED photometer, but it really gets interesting when testing them. In the first ground test, four photometers were connected to a four channel Hobo datalogger and left on my back patio all day. I expected to see the light intensity for each color begin to go up at sunrise, max out at around 10:00 AM when

■ FIGURE 6

Photometer Test



the sun went over the patio overhang, then decrease until sunset. Figure 5 shows the chart from that first test.

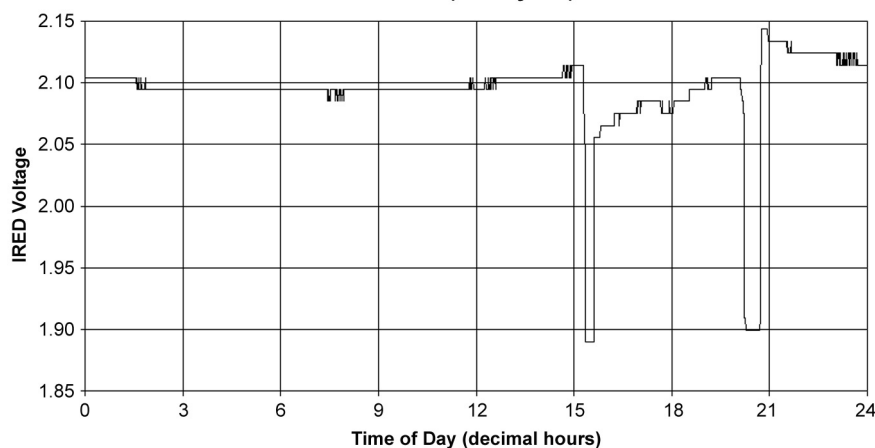
The sun passed through a cloud bank shortly before 7:00 AM, so I can understand the dip in light intensity at that time. The problem is that the yellow, infrared, and ultraviolet light intensities are identical to each other. I suspect that the datalogger has a common ground for all its sensor inputs and that one of the LEDs is clamping the currents (and therefore voltages) of the other LEDs. Therefore, in the next experiment, each photometer had a separate datalogger (Figure 6).

It's interesting how the green intensity rises quickly, but yellow takes a bit longer. I suspect that's because there's less yellow light refracted in the atmosphere, and what yellow light the photometer does see is primarily from the sun. At about 11:15 AM, the sun rose above the patio cover. Yellow intensity takes a nose dive when this happens, but there's still a lot of green light in the sky. So green and yellow light intensities make sense the way they behave on this chart.

Now take a look at the infrared output. Its output is very high until just before sunrise. It then takes a brief nose dive before climbing again at sunrise. The same thing occurs near sunset, even though the infrared LED cannot see the setting sun through the house. This chart is saying that the sky in the backyard is bright in infrared

■ FIGURE 7

Infrared (front yard)



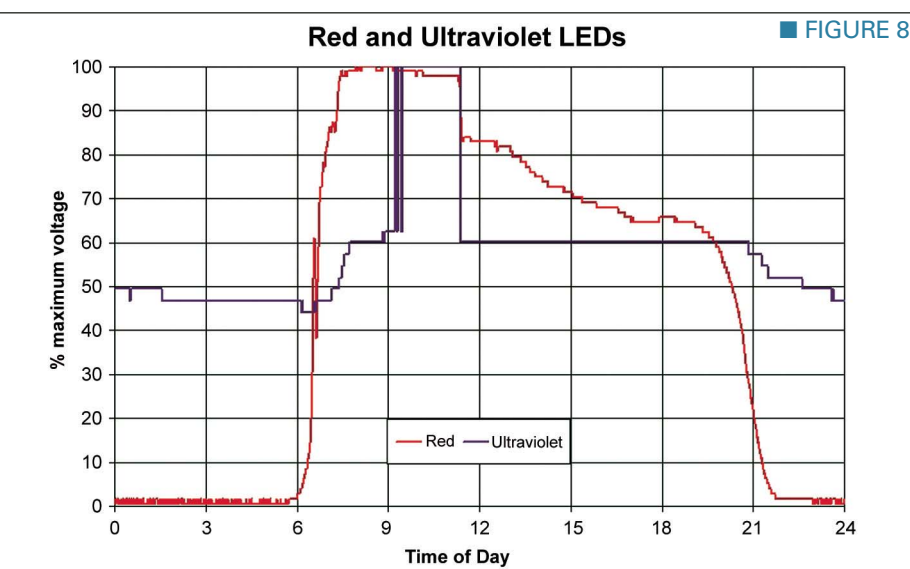
during the night. Why it is, I don't understand.

Now, I do have neighbors behind my backyard. To see if one of them has a bright infrared light source in their backyard (as part of a security system, perhaps) the experiment was run again, but this time with the infrared photometer sitting on my front porch. Figure 7 shows the chart I got from that run.

Whoa! What's going on here? Again, the sky is very bright in infrared at night. Then, just as the sun appears over the porch, the infrared intensity nose dives only to climb again as the sun comes into full view. Then, just as the sun sets, the same thing repeats. There are only two houses across the street and I can't imagine that they're infrared bright. Therefore, I'm left with something of an infrared mystery here.

A comparison of red and ultraviolet photometers gives the chart in Figure 8.

In this chart, the ultraviolet doesn't really peak until just after 9:00 PM. What's also surprising about the ultraviolet LED is that it produces a background current when in the dark. From measurements made to create the table in this month's column, I realized that the ultraviolet LEDs don't produce any significant current. Neither do the blue LEDs. This leads me to believe that blue and ultraviolet LEDs do not make good photometers. This may be due to their construction



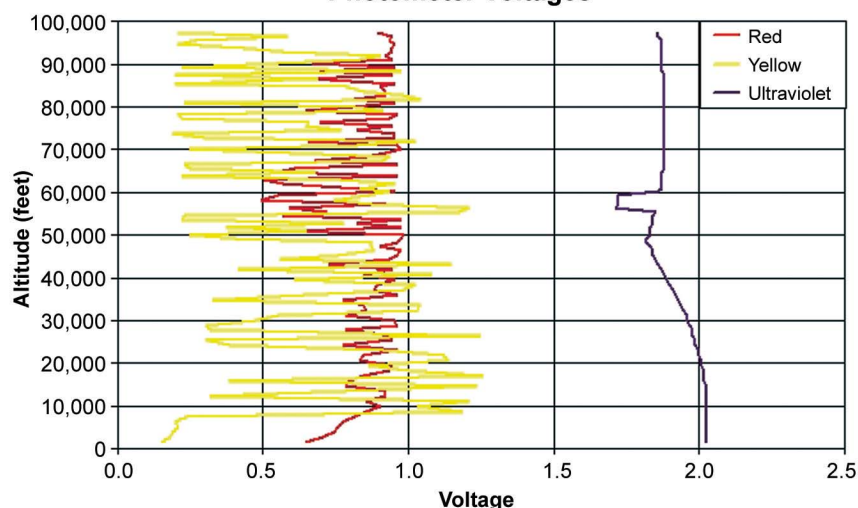
since they don't contain a silicon die.

This summer, one of my near space missions carried three LED photometers. After the interesting data I collected on the ground, I was excited to see what would happen in near space. The chart from that mission is shown in Figure 9.

The ultraviolet intensity decreased slightly until 60,000 feet (see the notch). From there, it held mostly steady (there's a slight increase). Based on the voltage measured across blue and ultraviolet LED photometers on the ground, I suspect this has to do more with changes in temperature. Notice that the yellow and red photometers are still sensitive to the pointing direction. That's why

■ FIGURE 9

NearSys 07C Photometer Voltages



THE ONSET PENDANT G LOGGER



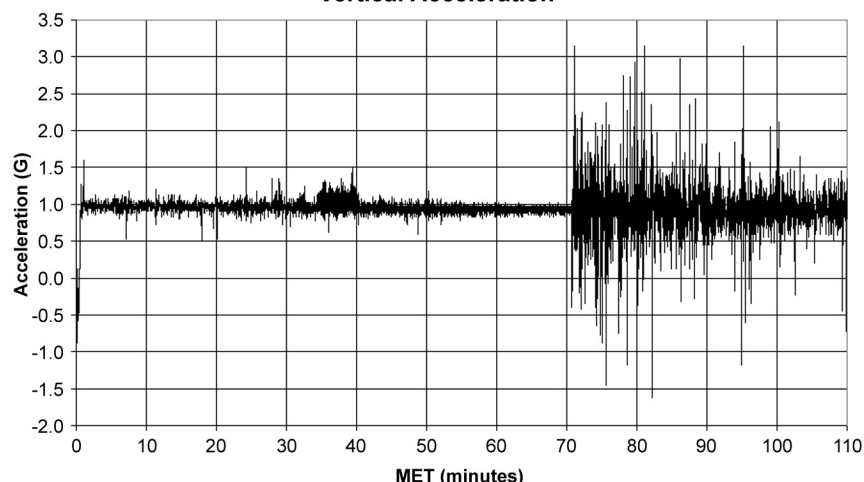
Last year, OnSet Computing (www.onsetcomp.com) introduced me to their Pendant G Logger. Upon hearing about this three-axis acceleration datalogger, I was excited to try it out. Like the company's other dataloggers, it's programmed for a mission then sent on its way. The keyword here though is programmed. I had one opportunity last year to fly the logger, but I forgot to program it before the mission. Finally this year, I did it right and have flown it on several near space missions. Needless to say, the results are very pleasing.

The Pendant G logger is a small, self-contained device. As you can see from the photo, it's not much larger than an old-fashioned box of matches at 0.9" x 0.5" x 0.4". Since air temperatures in near space can drop to -60 degrees or lower, the Pendant G Logger must be kept inside the near spacecraft module rather than outside. The Pendant G logger's 3G maximum acceleration works well for near space missions.

The sensor inside the logger can detect differences as small as 7% of a g or a 1.4 degree tip of the logger. You can tell if the recorded change in

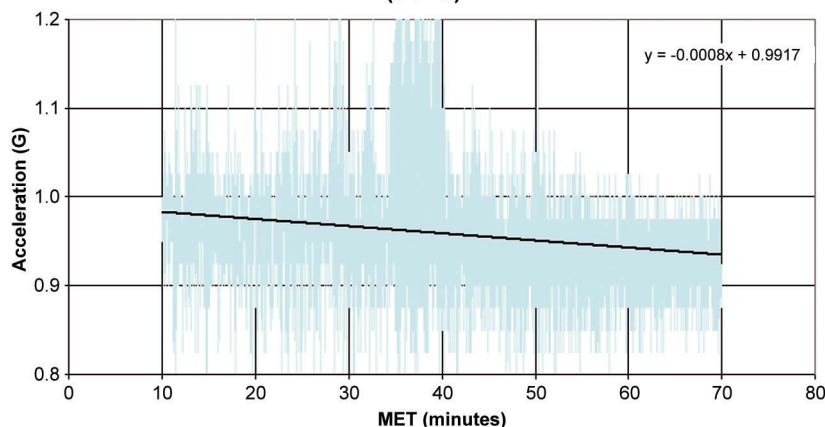
■ FIGURE B

NearSys 07A Vertical Acceleration



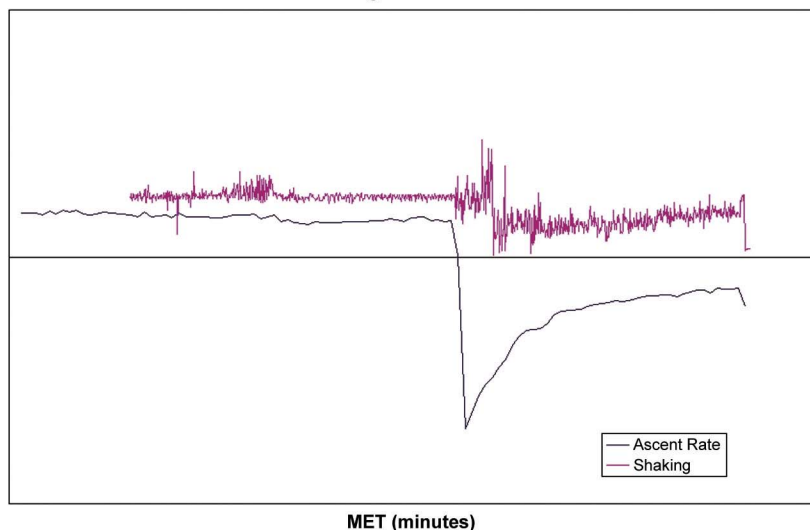
■ FIGURE C

NearSys 07A Horizontal Acceleration (trend)



■ FIGURE D

Shaking vs Ascent Rate



Sidebar continued ...

acceleration is due to a change in acceleration or due to tipping by noting if the acceleration in another axis changes to compensate.

The microcontroller inside the Pendant G Logger can digitize measurements as fast as 100 samples per second (the sample rate is set by the software used to program the logger). The logger's memory is large enough to hold 64K, or 65,536 measurements. At a sampling rate of 100 Hz, the logger will run out of memory in 10.9 minutes. Since a near space mission lasts closer to three hours than to 10 minutes, set the logger's sampling rate to 5 Hz or less. That's a maximum rate of five measurements per second.

The Pendant G Logger is inexpensive. A \$59 reader programs the logger and downloads its data, so you can't just purchase the Pendant by itself. However, you can purchase multiple Pendants and just one reader. That's a great option if you are running a BalloonSat workshop where several loggers are needed.

Figure B shows some of the data I've collected in near space with a Pendant G Logger. This is a chart of the vertical acceleration (the Y-axis) experienced by my near spacecraft. You'll notice that there's more variation in the acceleration for the first 40 minutes of the flight. At the 40-minute point, there's a greater burst of shaking (variation in acceleration). Then everything quiets down until the balloon bursts. You can tell when the balloon bursts in the chart. I've always assumed the interior of the near spacecraft experiences zero G initially after burst. But from this chart, we can see that there's so much shaking going on that no microgravity conditions are experienced during the descent.

Looking closely at this chart, I noticed that there's a tiny decrease in the acceleration until the balloon burst. Therefore, I used Excel to magnify this effect, create a trend line, and generate an equation describing this decrease in acceleration. The result is Figure C.

There's about a 7% decrease in the balloon's acceleration during its climb to 87,000 feet. At best, one percent of this is attributable to the reduction in gravity at high altitude (if even that much). So, I don't know where the other 6% comes from. I thought it might be from sensor drift, but I couldn't replicate this decrease in acceleration by letting the Pendant sit on the front porch where there is no change in acceleration.

If the decrease were due to temperature effects, then I would expect the drift to change directions as the interior

there's so much zigzagging in the data. The overall trend in yellow appears to be a slight decrease in intensity. There's no apparent trend in the red except that there's a wider variation in the red intensity around 60,000 feet. Curious.

So, what have I learned? First, I need to use diffused LEDs. Using eight water-clear LEDs still makes the photometer sensitive to its pointing direction. That's probably because their angle of emission is still too narrow for a photometer with LEDs every 45 degrees. Next, I need to find the source of the dark current in the infrared LEDs. I also need to find a substitute for blue and ultraviolet LEDs if I want an affordable blue and ultraviolet photometer.

The next LED photometer design will have a PICAXE-08M to digitize and record the data from eight (or more) LEDs. The PICAXE will only

record the locally minimum voltages in order to avoid sun pointing errors. Perhaps a coin cell can power this PICAXE LED photometer. If so, the LED photometers could be stacked together to form an array of photometers to make multi-spectral measurements.

If you'd like to experiment with a more sophisticated LED photometer, then check out the GLOBE Sun Photometer website Forest Mims

recommended at www.mcs.drexel.edu/~dbrooks/globe/globe_work.html. Those LED photometers use a LTC 1051 op-amp to convert current to voltage rather than a resistor. After checking out this website, then check out the Parallax *Earth Measurements* lab book for their photometer exercise (www.parallax.com).

Onwards and Upwards,
Your near space guide **NV**

Sidebar continued ...

temperature dropped and then rose again in the stratosphere. So, here's a mystery I need to investigate with another near space mission. (I just love when this stuff happens!)

In my final chart (Figure D), I combined climb rate based on GPS data with the vertical acceleration data from the Pendant G Logger.

In most near space flights, we observe a small decrease in the balloon's ascent rate. This "knee" in the ascent rate occurs around 40 minutes into the flight and may be signaling a change in the balloon's coefficient of drag. That is, the balloon becomes draggier at high altitude and it slows down. You'll notice that the amount of shaking experienced onboard the near spacecraft matches this change in ascent speeds. Therefore, there's more shaking early in the flight when the balloon is climbing at its fastest. At some point, the balloon slows down and the ride becomes a bit smoother.

Well, that's what I have for you regarding this great accelerometer. As a teacher, I think it would be a great tool to have in a high school or junior college physics lab. It's also a great sensor to launch on your next near space flight. I'll be sharing more data from this sensor with you in future articles. In the meantime, if you get one yourself, please share your results with me.

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■ BY FRED EADY

16 BITS EQUALS TWICE THE FUN

OVER THE YEARS, I'VE DESIGNED MOST of my really serious embedded projects around eight-bit PIC microcontrollers. As for the physical sizes of the eight-bit PICs I've used, I've done eight-bit microcontroller projects with the tiny six-pin 10F PIC devices. On the other side of that, I've put together more complex embedded designs with the outrageously powerful 80-pin PIC18F8722 and 100-pin PIC18F97J60. I must admit that there were times when I walked off the eight-bit Microchip path and camped out with some really interesting Philips 32-bit ARM microcontrollers. Although my ARM experiences were enlightening, not long after wandering off into ARMville, I eventually walked out of the 32-bit city and continued to follow the well-beaten eight-bit PIC path.

Microcontroller performance is directly proportional to the bandwidth of its internal busses. Thus, one would expect a well-designed 32-bit microcontroller to outperform any good eight-bit device. However, there's nothing wrong with doing things with eight-bit microcontrollers. The last time I had a conversation with Microchip's CEO, Steve Sanghi, he pointed out that the PIC16C54 was still a very big part of Microchip's income. In fact, some projects are so simple that the eight-bit microcontroller embedded within them is overkill. However, sometimes an eight-bit microcontroller may not have the computational strength to support the mission. And, if the prospective eight-bit microcontroller has the computational portion of the project covered, the eight-bit microcontroller you want to use may not have enough natural resources (SRAM, timers, UARTS, etc.) to successfully support the project. Fortunately, the folks at Microchip realize that. So, instead of just sitting on their very fine eight-bit horses, the PIC engineers in Arizona hit the 16-bit trail.

EIGHT MORE BITS

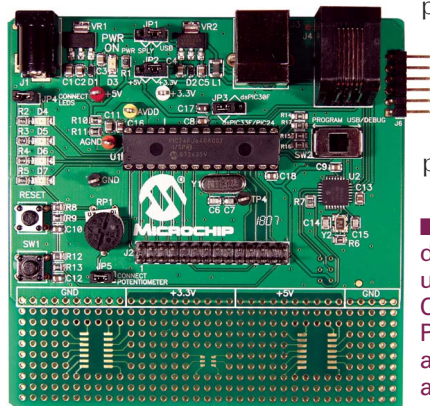
It is that simple. When you use a 16-bit PIC, you get eight more bits of internal bandwidth to work with. The very same Modified Harvard Architecture foundation that you enjoy with the eight-bit PIC family remains untouched in the new 16-bit PICs. However, with the 16-bit PICs, you get a 16-bit data path, 24-bit instructions, and a 24-bit addressing scheme, which is similar to that of the Microchip dsPIC digital signal controllers.

In addition, the 16-bit PIC family of devices allow you to map in portions of program memory into data space and access the program memory as if it were data. This feature of the 16-bit PIC is called PSV (Program Space Visibility).

I have to take a reality check every now and then. Not every one of you reading this installment of Design Cycle is a disciple of the Microchip PIC. So, if Modified Harvard Architecture sounds like a marketing term, it's not. Modified Harvard Architecture specifies the use of separate data and program storage spaces and differing data and program formats that have the ability to interact under the control of the programmer by way of separate busses. For instance, Modified Harvard Architecture allows us to store constant data in the program memory area and read the constant data just as if it were data stored in the data space (PSV). Data is normally stored in the SRAM area of a PIC with program memory space normally being the PIC's Flash memory area.

Modified Harvard Architecture antimatter is known as the Von Neumann Architecture. Von Neumann Architecture places the program and data in a single space.

Thus, the data and program are similar in format and reside in the same memory area. In the 1950-era computers, stored program concepts were invented in which the program and data were loaded into volatile



■ **PHOTO 1.** Remember the old muscle car days when big motors were commonly found under the hoods of unassuming Plain-Jane Camaros and Mustangs? The powerful PIC24FJ64GA002 is shown here lounging around with some LEDs, a pushbutton switch, and a cheap potentiometer. Hmmm ...

memory and executed from there. Von Neumann Architecture was (and is), in fact, the “stored-program concept.”

Data within a 16-bit PIC is also stored and addressed as a 16-bit package but we actually use the data in the normal eight-bit way. The least significant byte of the 16-bit data word is always found on an even address boundary (0,2,4,6, etc.). Accessing the most significant byte of the 16-bit data word tied to an even address boundary reveals the odd data bytes (1,3,5,7, etc.). A quick look at the linker script of the 16-bit device we will be discussing shows that our 16-bit PIC’s data space begins at address 0x0800 and is 0x2000 bytes in length:

```
//LINKER SCRIPT MEMORY AREA SNIPPET
MEMORY
{
    data (a!xr) : ORIGIN = 0x800,      LENGTH = 0x2000
    reset       : ORIGIN = 0x0,        LENGTH = 0x4
    ivt         : ORIGIN = 0x4,        LENGTH = 0xFC
    aivt        : ORIGIN = 0x104,      LENGTH = 0xFC
    program (xr) : ORIGIN = 0x200,      LENGTH = 0xA9FC
    config2     : ORIGIN = 0xABFC,     LENGTH = 0x2
    config1     : ORIGIN = 0xABFE,     LENGTH = 0x2
}
```

Thus, 0x27FE is the least significant byte of data just before the last and most significant byte of data at 0x27FF. There are some other things we can take away from the linker script snippet:

- The 16-bit PIC’s reset vector is located at 0x0.
- The 16-bit PIC’s Interrupt Vector Table begins at 0x04.
- The 16-bit PIC’s Alternate Interrupt Vector Table begins at 0x104.
- The 16-bit PIC’s program space begins at 0x200.
- The 16-bit PICs’s Configuration Words reside at 0xABFC and 0xABFE.

Thus far, we have a 16-bit PIC that supports a 16-bit data path, a 24-bit instruction set, and a 24-bit Program Counter. You can also add a 16-bit x 16-bit Working Register Array and multiple 16-bit Timer/Counters to the list of 16-bit PIC features. The 16-bit x 16-bit Working Register Array contains 16-bit register space for the 17-bit x 17-bit single-cycle hardware multiplier and the 32-bit x 16-bit hardware divider, in addition to general-purpose 16-bit registers.

It’s obvious that the 16-bit PIC was designed to crunch numbers. However, a PIC just isn’t a PIC unless you have the ability to pound on stuff with the PIC’s I/O pins. With that thought in mind, let’s do some touchy feely on some real 16-bit PIC hardware.

BLINKING LEDs WITH THE PIC24FJ64GA002

Believe it or not, everything we’ve discussed up to this point concerning 16-bit PICs has been “general-purpose.” Yep. All of the stuff you’ve just read about is simply standard equipment on a 16-bit PIC. Now that you have a basic understanding of what

a 16-bit PIC is made of, let’s look at what it takes to put some code behind a 16-bit PIC and exercise the 16-bit hardware.

There’s no better way to learn about a new PIC than blinking some LEDs and forcing some characters through its UART. Blinking LEDs and sending UART-based messages are basically what the PIC24FJ64GA002-based demo board you see in Photo 1 is designed to do. Don’t be fooled. Blinking LEDs with a PIC may sound simple. However, there are some things you need to know about the PIC24FJ64GA002 before you can successfully illuminate and extinguish an LED alternately using a PIC24FJ64GA002 I/O pin. For example, take a look at Figure 1. Quick. Tell me where you would hang your LED. Is RA0 really a digital I/O pin or is it in the AN0 analog mode? What about RB0? Is it really the I/O pin RB0? What does the RB0 multiplexed function RP0 represent? (Get my point?)

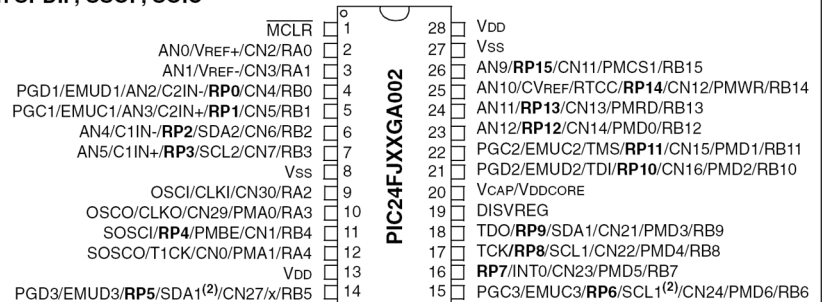
The pin multiplexing scheme employed by the PIC24FJ64GA002 may seem at first to be very complex. However, the key to understanding any complex idea is breaking down the problem into smaller manageable parts. So, let’s play the cards we were dealt. As you can see in Schematic 1, the PIC24FJ64GA002 demo board has four onboard LEDs, which are attached to RB12, RB13, RB14, and RB15. Consulting the PIC24FJ64GA002 datasheet, I learned that all of the PIC24FJ64GA002’s I/O pins are configured as inputs following a reset. Since the I/O pins that are supporting the LEDs are multiplexed with analog-to-digital (A-to-D) inputs, let’s be safe and dedicate the LED-toting I/O pins to a digital role. This is easily done by setting all of the bits within the A/D Port Configuration Register (AD1PCFG). The AD1PCFG resets to zero indicating all of the ANx A-to-D inputs are enabled. Setting the AD1PCFG register bits to logical 1 disables the associated A-to-D input and puts the selected port pin into digital mode. Here’s the Microchip C30 C compiler statement that erases all of the PIC24FJ64GA002’s A-to-D inputs:

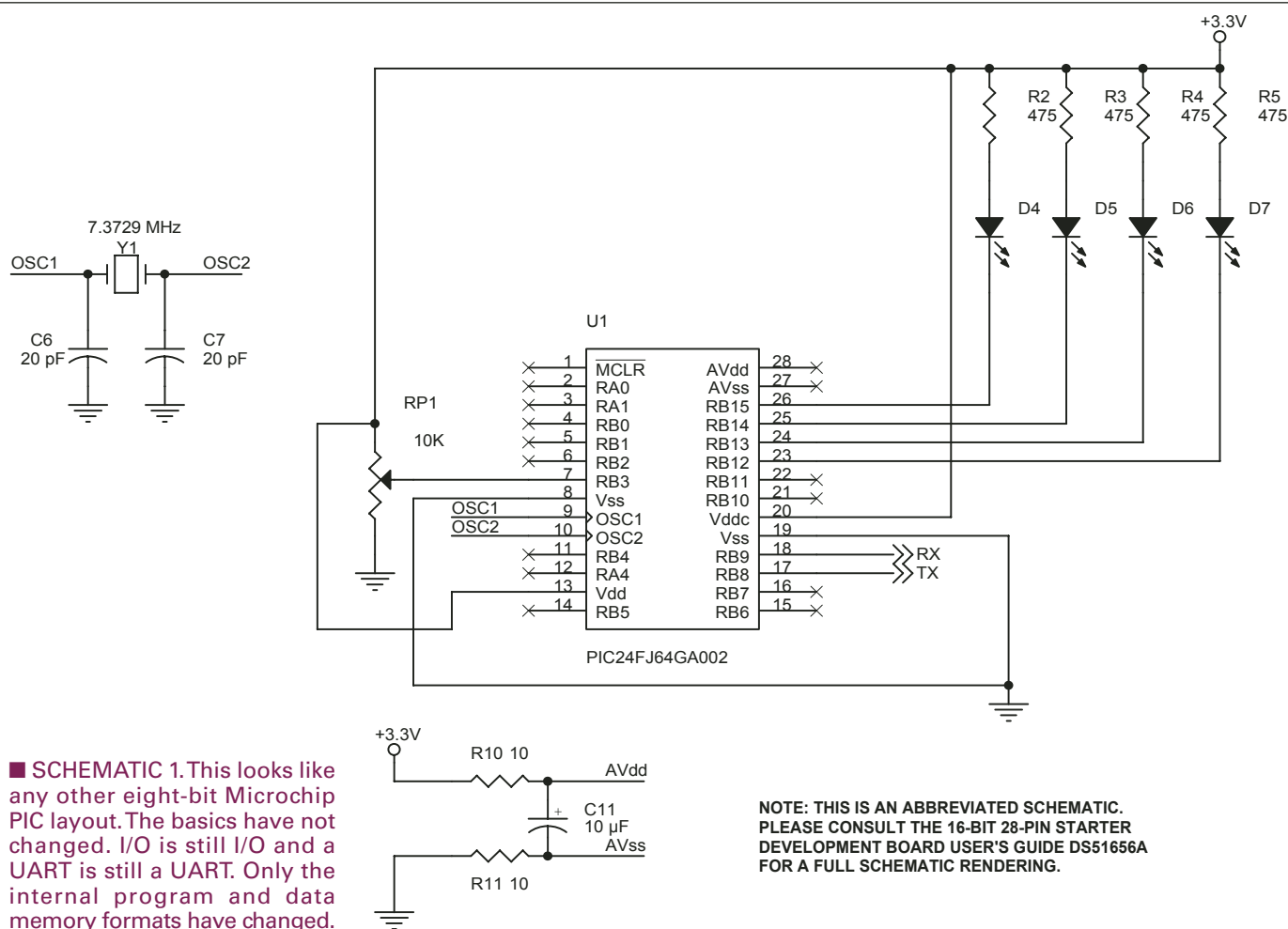
```
AD1PCFG = 0x1FFF;
```

If you’re wondering why the 0x1FFF is not 0xFFFF, there are only 13 possible A-to-D inputs. The three most significant bits of the AD1PCFG register default to zero (0b0001111111111111). The PIC24FJ64GA002 only supports AN0-AN5 and AN9-AN12. By using the 0x1FFF value, we’re actually turning off A-to-D

■ **FIGURE 1. Note the heavy use of pin function multiplexing. The bold RPn pins are remappable peripheral pins. The RPx pins can be configured to function as timer I/O, UART I/O, SPI I/O, input/output capture I/O, PWM outputs, or comparator outputs.**

28-Pin SPDIP, SSOP, SOIC⁽¹⁾





inputs that the PIC24FJ64GA002 doesn't even have.

Although the PIC24FJ64GA002 is a 16-bit microcontroller, it still has pieces of itself that follow the eight-bit tradition in a 16-bit way. Now that we've disabled the A-to-D inputs, the next step we will take is to condition the Port B I/O pins to drive the quartet of LEDs. This is done with the TRISB statement:

```
TRISB = 0x0FFF;
```

The TRISB C30 statement looks just like an eight-bit TRISB C statement with eight extra bits. I/O pins RB12 through RB15 are now output pins. According to what we see in Schematic 1, we can now turn on each individual LED by writing a zero to the corresponding LATB bit. Piece of cake! We didn't do anything differently with the 16-bit PIC24FJ64GA002 than with an eight-bit PIC except incorporate eight extra bits into the mix.

USING THE PIC24FJ64GA002 UART

What do you think? Can we just waltz through the UART setup just as if we were in eight-bit PIC land? Yes and no. Take another look at Figure 1. Do you see TX and RX assigned to any PIC24FJ64GA002 I/O pins? Nope.

No worries. Here's where we put the PIC24FJ64GA002's

remappable peripheral pin feature to work. The peripheral pin select mechanism within the PIC24FJ64GA002 is used as a peripheral force multiplier. There are only so many peripherals that can be statically assigned to a 28-pin device such as the PIC24FJ64GA002. The peripheral pin select feature allows the PIC24FJ64GA002 programmer to select the peripherals required for the project and place them on an available RPN pin. The really cool thing about the peripheral pin select feature is that the PIC24FJ64GA002 programmer can map multiple peripheral inputs and outputs to multiple RPN pins.

We need to deploy our UART. The PIC24FJ64GA002 has a pair of UARTs. So, we will activate UART1. Let's begin by specifying the RX input for UART1. Again, we'll work with the cards in hand. Schematic 1 tells us that the UART1 RX input is located on I/O pin RB9. Figure 1 tells us that pin RB9 doubles as remappable peripheral pin RP9. That leads us to Figure 2, which maps the U1RX function to the RPINR18 (Remappable Pin Input) register. Note that the RPINR18 register is associated with UART1 only. The RPINR18 register contains a pair of five-bit fields which we will use to map the U1RX function to the PIC24FJ64GA002's RB9 I/O pin. In the case of input mapping, we need only fill in the value representing the RPN pin we wish to map to the UART1 RX peripheral. That value would be 9. Here's how the C30 input mapping statement looks:

■ **FIGURE 2.** I really had to put the old thinking cap on when I first encountered peripheral pin select. However, as you can see, it's not that difficult of a concept to grasp.

```
// Pin RP9 = U1RX
RPINR18bits.U1RXR = 9;
```

The RPINR18 register is 16 bits in length with the least significant byte holding the five U1RX peripheral bits. The RPINR18 register contains 0x1F09 after we assign the U1RX function to remappable I/O pin RP9. Note that we didn't have to TRIS RB9 as an input. That's because the peripheral function overrides the I/O pin's digital properties. It's okay to be safe and write a logical 1 to input pin RP9, if you wish to.

That was easy. Now let's mate an RPn pin to the U1TX function. In Figure 3, we see that the U1TX function is associated with Output Function 3. Before we get away from Figure 3, note that the NULL function is used to disable RPn outputs. The NULL function is assigned to all of the RPn outputs following a reset.

The peripheral pin select output mapping process is similar to the peripheral pin select input mapping process. However, instead of using the RPn "n" value to fill the five-bit RPINRxx configuration field, output mapping uses the Output Function number to populate the appropriate five-bit area of the RPORx (Remappable Pin Output Register) configuration field.

Schematic 1 tells us that the U1TX function is expected to be mapped to the PIC24FJ64GA002's RB8 I/O pin. Just like the RPINRxx registers, each RPORx register contains a pair of five-bit configuration fields. RPOR0 houses configuration bits for RP0 and RP1. RPOR1 is used to configure RP2 and RP3. Logic tells us that RPOR4 will hold the output mapping configuration bits for RP8 in its least significant byte with RP9 configuration bits in its most significant byte. Recall that we are using RP9 as a peripheral input. We must fill in the RPOR4 register's five-bit RP8 field with a 3 to map the RP8 output to the U1TX function. Here's the C30 C source code to do just that:

```
RPOR4bits.RP8R = 3;    // Pin RP8
                        = U1TX
```

Following the execution of the U1TX mapping code, the RPOR4 register will contain 0x0003.

The next step in bringing up our UART1 involves calculating the Baud Rate Generator value (BRGVAL). The

Input Name	Function Name	Register	Configuration Bits
External Interrupt 1	INT1	RPINR0	INTR1<4:0>
External Interrupt 2	INT2	RPINR1	INTR2R<4:0>
Timer2 External Clock	T2CK	RPINR3	T2CKR<4:0>
Timer3 External Clock	T3CK	RPINR3	T3CKR<4:0>
Timer4 External Clock	T4CK	RPINR4	T4CKR<4:0>
Timer5 External Clock	T5CK	RPINR4	T5CKR<4:0>
Input Capture 1	IC1	RPINR7	IC1R<4:0>
Input Capture 2	IC2	RPINR7	IC2R<4:0>
Input Capture 3	IC3	RPINR8	IC3R<4:0>
Input Capture 4	IC4	RPINR8	IC4R<4:0>
Input Capture 5	IC5	RPINR9	IC5R<4:0>
Output Compare Fault A	OCFA	RPINR11	OCFAR<4:0>
Output Compare Fault B	OCFB	RPINR11	OCFBR<4:0>
UART1 Receive	U1RX	RPINR18	U1RXR<4:0>
UART1 Clear To Send	U1CTS	RPINR18	U1CTSR<4:0>
UART2 Receive	U2RX	RPINR19	U2RXR<4:0>
UART2 Clear To Send	U2CTS	RPINR19	U2CTSR<4:0>
SPI1 Data Input	SDI1	RPINR20	SDI1R<4:0>
SPI1 Clock Input	SCK1IN	RPINR20	SCK1R<4:0>
SPI1 Slave Select Input	SS1IN	RPINR21	SS1R<4:0>
SPI2 Data Input	SDI2	RPINR22	SDI2R<4:0>
SPI2 Clock Input	SCK2IN	RPINR22	SCK2R<4:0>
SPI2 Slave Select Input	SS2IN	RPINR23	SS2R<4:0>

PIC24FJ64GA002 demo board is natively clocked at 7.372800 MHz. Just for grins, let's use the PIC24FJ64GA002's PLL to boost the basic clock frequency by a factor of two. I like running my serial ports at 57600 bps with eight data bits, one stop bit, and no parity. That's enough information to allow the C30 compiler to perform the math needed to determine the BRGVAL value. Again, this is no different than what we would do with an eight-bit microcontroller's UART:

```
#define YFREQs 7372800    // Crystal frequency
#define PLLMULT 2        // On-chip PLL setting
#define FCY YFREQ*PLLMULT // Instr Cycle Freq
#define BAUDRATE 57600
#define BRGVAL ((FCY/BAUDRATE)/16) - 1
```

Once we have the calculated BRGVAL, we can load it into the UART's Baud Rate Generator subsystem like this:

```
U1BRG = BRGVAL;
```

As it turns out, we only need to enable UART1 by setting bit 15 of the U1MODE register. All of the other bit values within the U1MODE register just happen to match my speeds and feeds when they are set to zero. This is very clever on the part of the PIC24FJ64GA002's engineering staff. The U1MODE register resets to

■ **FIGURE 3.** Compared to input mapping, output mapping is the same but different. Instead of filling the five-bit register mask with n of RPn, we use a predetermined function number for the RPORn five-bit register value.

Function	Output Function Number ⁽¹⁾	Output Name
NULL ⁽²⁾	0	NULL
C1OUT	1	Comparator 1 Output
C2OUT	2	Comparator 2 Output
U1TX	3	UART1 Transmit
U1RTS ⁽³⁾	4	UART1 Request To Send
U2TX	5	UART2 Transmit
U2RTS ⁽³⁾	6	UART2 Request To Send
SDO1	7	SPI1 Data Output
SCK1OUT	8	SPI1 Clock Output
SS1OUT	9	SPI1 Slave Select Output
SDO2	10	SPI2 Data Output
SCK2OUT	11	SPI2 Clock Output
SS2OUT	12	SPI2 Slave Select Output
OC1	18	Output Compare 1
OC2	19	Output Compare 2
OC3	20	Output Compare 3
OC4	21	Output Compare 4
OC5	22	Output Compare 5

0x0000 and all of the most commonly used UART parameters (eight data bits, no parity, one stop bit) are active when their respective bits are set to zero:

```
U1MODE = 0x8000;           // UART config = 8-n-1, enabled
```

Enabling the UART1 transmit and receive I/O is just as easy as configuring its speeds and feeds. Setting a single bit in the U1STA (UART1 Status) register is all it takes to bring UART1's I/O online:

```
U1STA = 0x0400;           // Enable TX and RX
```

The easiest way to test our UART1 configuration is to fire up a 57600 bps Tera Term Pro terminal session and execute this piece of code:

```
_UIRXIF=0;                 //Clear UART RX Interrupt Flag
while(1)
{
    while (_UIRXIF==0);     // Wait for a character
    U1TXREG = U1RXREG;       // Copy Rx char to Tx
    while(!U1STAbits.TRMT); // Send it
    _UIRXIF=0;              // Clear UART RX
                           // Interrupt Flag
}
```

If everything is in order, the little code snippet I just presented to you will echo each character you type into the Tera Term Pro terminal emulator session. If you decide to put my code snippet to the test, I think you'll find that everything is in order.

MEASURING VOLTAGE WITH THE PIC24FJ64GA002

So far, this 16-bit stuff has been a walk in the park. Let's flex our muscles and make an attempt of extending our success by cranking up the PIC24FJ64GA002's analog-to-digital converter subsystem. Again, you're going to see that there is a bunch of eight-bit flavor in the 16-bit A-to-D converter operations.

The first thing we must do is open up an analog input I/O pin. Consulting Schematic 1, we see that the PIC24FJ64GA002 demo board's potentiometer wiper is tied to AN5. Thus, this line of C30 C source will put AN5 into analog input mode:

```
AD1PCFG = 0x1FDF;         //Activate AN5 for ADC use
```

Recall that earlier we loaded AD1PCFG with 0x1FFF to kill off all of the analog inputs. Here, I simply dropped the bit associated with AN5 to a logical zero to enable the AN5 pin to the A-to-D circuitry.

There are lots of fancy things we can do with how we sample and obtain the converted A-to-D data. I'm not going to get tricky here. We'll manually control the sample and conversion process using the SAMP and DONE bits. Thus far, we have seen a great deal of similarity in 16-bit and eight-bit peripheral operations. The 16-bit A-to-D subsystem embedded within the PIC24FJ64GA002 is following suit. The only deviation from the

eight-bit A-to-D operation is the use of the SAMP bit in the 16-bit A-to-D conversion process. After all was said and done, I cleared one bit and set four bits to completely initialize the PIC24FJ64GA002's A-to-D converter module. Here's how it all came out from the C source code perspective:

```
//AD1PCFG = 0x1FFF;         //All analog pins digital
AD1PCFG = 0x1FDF;         //Activate AN5
AD1CON1 = 0x0000;         //SAMP=0 starts conversion
AD1CHS = 0x0005;         //Select AN5 as ADC input
AD1CON2 = 0x0000;
AD1CON3 = 0x0002;         //Manual sample
AD1CON1bits.ADON = 1;     //power up ADC subsystem
```

Putting together the PIC24FJ64GA002's A-to-D converter initialization code is akin to building a model RC airplane. It may look good sitting still, but will it fly? We can easily flight test our initialization code by adding a bit of code to perform the sampling, conversion, and data retrieval. We've already proven our UART1 driver code. So, why not press the UART1 driver into service via the printf function to display our A-to-D conversion results.

To use the C30 C compiler's built-in printf() functionality, we must add stdio.h to our include list. I also had to provide a heap value to the Linker command line. The heap entry can be found in the MPLAB IDE Project Build Options behind the MPLAB LINK30 tab. I entered a heap size of 1024 just to make sure I could get things to run. That value can, of course, be tweaked to your satisfaction.

As you can see in the A-to-D driver source, the SAMP bit is toggled with an integral delay to end the sample process and begin the conversion process. We then wait for the DONE bit to set indicating the end of the conversion and the transfer of the conversion results into the A-to-D conversion buffer, ADC1BUF0. The A-to-D conversion results are then immediately sent to the Tera Term Pro terminal emulator for display via the printf function:

```
unsigned int delayval,i;
//Analog-to-Digital conversion driver
while(1)
{
    AD1CON1bits.SAMP = 1;
    for(delayval=0; delayval<1000; ++delayval)
        ++i;
    AD1CON1bits.SAMP = 0;
    while(!AD1CON1bits.DONE);
    ADCVal = ADC1BUF0;
    printf("ADC TICK COUNT = %04d\r",ADCVal);
}
```

Once I compiled and loaded the A-to-D converter driver, I could twist the demo board potentiometer to its extents and read 0 minimum and 1023 maximum. That matches up perfectly with what we should see from a 10-bit A-to-D converter system. I tried to put the pot in the middle of its rotation and got pretty close as you can see by the value displayed in the Tera Term Pro emulator window in Screenshot 1.

BLINK THOSE LEDS, FRED!

Geez! We've been so busy firing up UARTs and A-to-D

converters, I almost forgot to show you how to blink those LEDs. No, I'm not going to show you how to manually toggle the LEDs. We're going to do this the fancy "New York" way using a timer and interrupts.

Let's use TIMER1 as the blink timer. What we must do to put TIMER1 in control of the blink rate is to preload a timing value into the PR1 register. When we turn TIMER1 loose, it will count up towards the preloaded PR1 value. When the TIMER1 count is equal to the PR1 preloaded value, an interrupt is generated. TIMER1 is reset when the interrupt occurs and the count-match-interrupt-reset operation I just described is performed again. Our human brains aren't capable of keeping up with anything that flashes at a rate of 60 Hz or better, and if we don't put some prescaling on the TIMER1 count clock, the LEDs will seem to be on constantly and appear dim. So, we'll prescale the TIMER1 source clock 1:256. The values you see in my LED Blinker driver code will illuminate the LEDs for about 270ms and extinguish them for the same amount of time in an alternating pattern. The result is that you see a 2Hz Flash rate. Here's the LED Blinker timer source code:

```
TMR1 = 0;           // Clear timer 1
PR1 = 0x3D0A;       // Interrupt every 270 ms
IFS0bits.T1IF = 0;  // Clear interrupt flag
IEC0bits.T1IE = 1;  // Set interrupt enable bit
T1CON = 0x8030;     // 1:256 prescale, start TMR1
```

Once TIMER1 begins its timing cycles, the real work (blinking those LEDs) is performed by a line of code within the interrupt handler:

```
void __attribute__((interrupt, no_auto_psv))
_T1Interrupt(void)
{
    IFS0bits.T1IF = 0; //Clear interrupt
    flag
    LATB ^= 0xF000;    //Toggle LEDs
}
```

SOURCES

■ **Microchip** (www.microchip.com) — C30 C Compiler; MPLAB ICD2; REAL ICE; PIC24FJ64GA002; MPLAB IDE; 16-bit 28-pin demo board

■ **Tera Term Pro** (<http://hp.vector.co.jp>)

METHODICAL MADNESS

You and I have managed to work our way through putting some essential 16-bit peripherals online. Along the way, we discovered that we can take all of that eight-bit experience we have and apply it in the 16-bit PIC world.

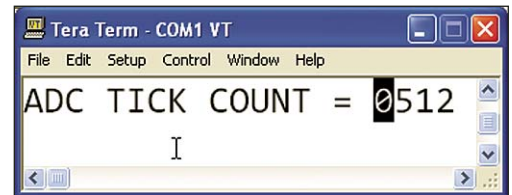
If you wish to continue on the 16-bit trail, you'll need a copy of the Microchip C30 C compiler, which can be had as a student edition from the Microchip website. You'll also need an MPLAB ICD2 or Microchip REAL ICE to program and debug your PIC24FJ64GA004 family member. I used a Microchip REAL ICE to prepare the code for this month's discussion. Finally, you'll need to get a copy of the MPLAB IDE and a PIC24FJ64GA002 datasheet from the Microchip website. I'll supply the source code we discussed as a download from the *Nuts & Volts* website (www.nutsvolts.com).

Now that you've seen how easy it is to put a 16-bit PIC into your project, add one to your Design Cycle. **NV**

■ **SCREENSHOT 1.** The default bit architecture of the PIC24FJ64GA002's analog-to-digital configuration registers make getting results like these easy.

CONTACT THE AUTHOR

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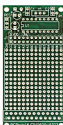
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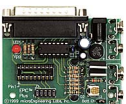
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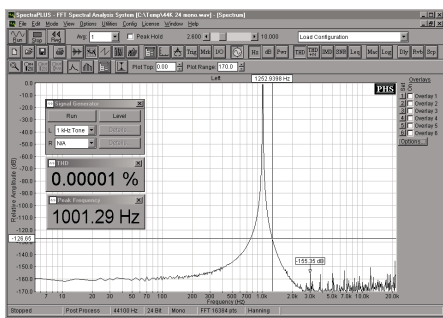


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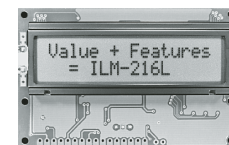
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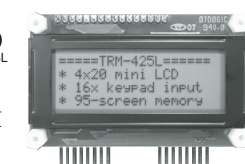
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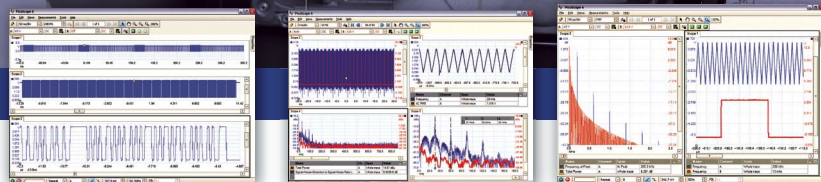
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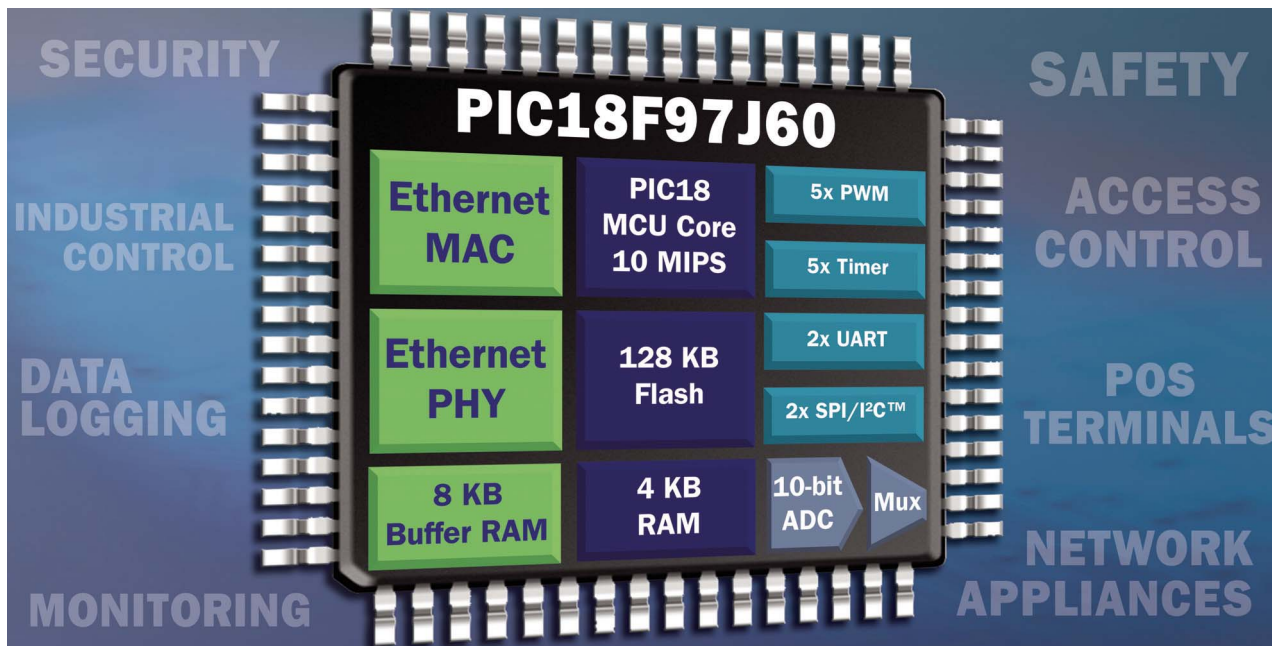
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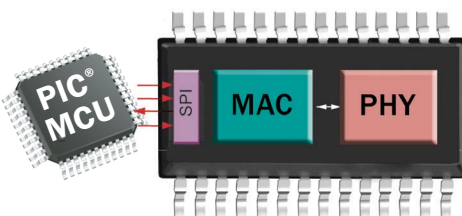
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PICBASIC PRO, EXCEL, AND THE BEGINNER

GOOD THINGS COME TO THOSE WHO WAIT. This is a common saying, but the real question is how long do I have to wait? Some would say it all depends on how you define a "good thing."

In my case, several years ago I asked the guys at microEngineering Labs for a sample version of their PICBASIC PRO compiler. You might even say I was a pest. It has always been my opinion that a demo version was the best way for a beginner to learn for very little cost. I also wanted a demo version for selfish reasons, so I could include it in educational training books that I'm finally getting a chance to work on. Eventually, microEngineering Labs released a sample version. It was worth the wait. I've used it here in earlier installments of this column, and have always been grateful for that demo.

I ran into the owner of microEngineering Labs at this year's Microchip Technology Masters Conference, and I told him I get a lot of reader feedback both from this column and elsewhere that many beginners would like to work with the eight-pin PIC® MCUs. I asked him if he would consider adding an eight-pin part to the

sample version for those just getting started. It was the first and only time I asked and, to my surprise, he delivered it to the world only a couple of weeks later. In fact, microEngineering Labs did better than that — they also added the 14-pin PIC16F688 and the 20-pin PIC16F690, which is the same part used in the PICKit™ 2 Starter Kit that I talked about last month.

You might be thinking, "Who cares; why is this worth mentioning?" In a general sense, it isn't that big of a deal to some; but to many beginners out there that still want a simple platform to get started with without making a big investment, it's a huge bonus.

Many reader comments state that they like what they see in PICBASIC PRO, but are concerned that they will not understand programming well enough to make it worth investing \$250 up front. Well, now the beginner can use an off-the-shelf eight-pin, 14-pin, or 20-pin PIC MCU and a simple programmer to create some very interesting projects — within the 31 command limit set by the sample version of PICBASIC PRO. The big deal in my mind is that, when a beginner takes this path, they can successfully program a PIC MCU and get into that comfort zone of knowing they can do it. The only thing left to do after that is to decide when they want or need to

spend the \$250 to get the full version.

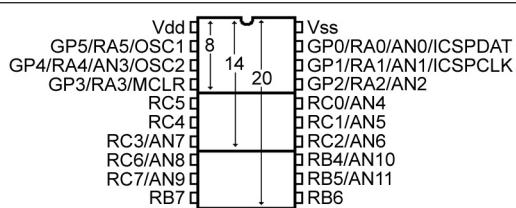
Starting out with these smaller parts has the advantage of using the latest Microchip PIC MCU technology. All three of these parts have internal oscillators and internal MCLR pull-up resistors. Meaning that, after it's programmed, all you need is 5V and ground to make the chip function. In fact, you can even run them from less than 5V. Using a few AA batteries will often work, so the intimidation factor is even less.

These parts also share a common pinout for the upper eight pins, as shown in Figure 1. This makes using these MCUs easier, because they can all share the same development board. I think these are some of the greatest parts for a beginner to use, and now you can program them with the free PICBASIC PRO sample version from www.melabs.com.

PICKIT 2 USART TOOL

As I mentioned, with the sample version of PICBASIC PRO, you still need a hardware programmer to load the code into the chip. I've talked about many of them in the past, including my own design — which is now only available at **BeginnerElectronics.com**, since my site no longer sells products other than my books. I wanted to quickly test out this new demo version for this article while also trying out the new PICKit 2 standalone programming interface version 2.40,

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■ FIGURE 1. Common Pinout.

■ FIGURE 3. PICKit 2 UART Tool Interface.

which runs by itself outside of Microchip's MPLAB® Integrated Development Environment (IDE) (shown in Figure 2). One of the features that I wanted to test out is a UART tool, under the "Tools" menu item.

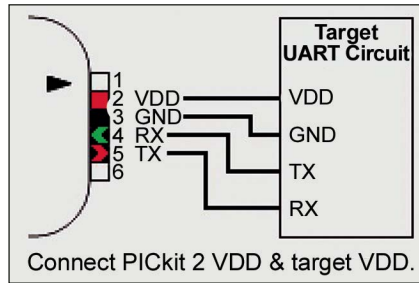
I could not have picked a better time for this new demo version of PICBASIC PRO to be released, so I could test it with this new PICKit 2 interface. It's killing two birds with one stone (another cliché). One of the limitations of these smaller MCUs is that the package size doesn't leave enough space for the debug silicon. If you want to debug in-circuit with Microchip's typical debug tools, then you have to use a special adapter. With this new software interface, I had hoped to create a simple, alternative in-circuit debugger.

SERIAL IN-CIRCUIT DEBUGGER

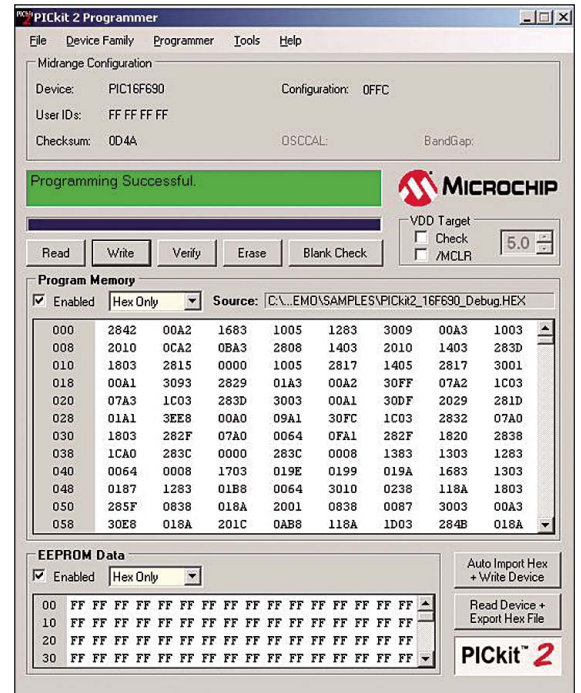
For these smaller parts without the debug silicon, I've often thought about using some kind of serial output statement within the PICBASIC PRO program to send status information to a PC. This way, I wouldn't need to add any special adapters. The problem was I needed some type of RS-232 circuitry for reliable communication back to the PC — which kind-of defeated the whole "get around the adapter" idea. The PICKit 2 UART tool seemed to be the answer, and offered a USB connection, as well.

Figure 3 shows the connection interface the UART tool uses. These are the same connections used for programming the MCU, so I didn't have to wire anything up separately. One exception is that I had to supply power to the development board externally, rather than power it directly from the PICKit 2 connection — but that's not tough.

For this test, I decided to use the PICKit 2 Low Pin Count demo board that's included with the PICKit 2 Starter Kit I covered in last month's article. I also decided to use a PIC16F690



(since I didn't have any PIC12F683s or PIC16F688s in my basement lab). On the PIC16F690 (and PIC16F688), the RA0 pin (GP0 on the PIC12F683) is located at the same pin in the 20-pin socket, so this technique should work on any of these micro-controllers. By sending data serially out the connection to the PICKit 2 connector, the PICKit 2 will convert it to USB format and then the GUI software will display the information. This means a simple serial command inside the PICBASIC PRO program can send back the status of a variable or send some kind of message to the PC. This seemed easy enough to do with a SEROUT command, but then I remem-



■ FIGURE 2. PICKit 2 Standalone Programmer Interface.

bered that PICBASIC PRO has a built-in DEBUG command that is just for this type of communication. My path was set to test this idea, and Listing 1 shows the resulting program.

Listing 1 is very easy to follow, but

LISTING 1

```
DEFINE DEBUG_REG PORTA
DEFINE DEBUG_BIT 0
DEFINE DEBUG_BAUD 2400
DEFINE DEBUG_MODE 0
```

```
ANSEL = 0
CM1CON0 = 0
CM2CON0 = 0
TRISC = 0
```

```
LEDs var byte
```

```
loop:
```

```
for LEDs = 0 to 15
```

```
  debug LEDs
  debug #LEDs,$0D, $0A
```

```
  PORTC = LEDs
```

```
  pause 1000
```

```
next
```

```
Goto loop
```

```
  ' Set DEBUG Port to PORTA
  ' Use pin A0 of PORTA for DEBUG
  ' Set Baud rate to 2400
  ' Communicate in True Mode
```

```
  ' Initialize A/D ports off
  ' Initialize Comparator 1 off
  ' Initialize Comparator 2 off
  ' All PORTC set as outputs
```

```
  ' Establish counter variable
```

```
  ' Step through Binary count from 0 to 15
```

```
  ' Monitor variable value through PICKit
  ' 2 Window (Hex Mode)
  ' For Data Log to Excel File mode
  ' (ASCII Mode)
```

```
  ' Make LEDs on board match Variable
  ' value
  ' Delay one second to watch LEDs
```

```
  ' Loop through this forever
```

LISTING 1A

```

DEFINE DEBUG_REG PORTA      \ Set DEBUG Port to PORTA
DEFINE DEBUG_BIT 0          \ Use pin A0 of PORTA for DEBUG
DEFINE DEBUG_BAUD 2400      \ Set Baud rate to 2400
DEFINE DEBUG_MODE 0         \ Communicate in True Mode

```

LISTING 1B

```

ANSEL = 0                  \ Initialize A/D ports off
CM1CON0 = 0                \ Initialize Comparator 1 off
CM2CON0 = 0                \ Initialize Comparator 2 off
TRISC = 0                  \ All PORTC set as outputs

LEDs var byte              \ Establish counter variable

```

LISTING 1C

```

loop:
for LEDs = 0 to 15          \ Step through Binary count from 0 to 15
    debug LEDs              \ Monitor variable value through PICKit
                             \ 2 Window (Hex Mode)
    debug #LEDs,$0D, $0A     \ For Data Log to Excel File mode
                             \ (ASCII Mode)

    PORTC = LEDs            \ Make LEDs on board match Variable
                             \ value
    pause 1000              \ Delay one second to watch LEDs

next

Goto loop                  \ Loop through this forever

```

I'll step through some of the details. Refer to Listing 1A. At the top are the setup `DEFINEs` for the `DEBUG` command. Some of these are default, but I set them up anyway. I make the `DEBUG` command communicate through `PORTA` pin `RA0` at 2400 baud in True mode. True mode means that the `PICKit 2` has an inverter built in, so a true RS-232 signal format is

required (though it ends up being a USB format, in the end).

The next section shown in Listing 1B is dedicated to setting up the `PIC16F690`. Port A defaults to analog inputs, so I have to clear the `ANSEL` register to turn off the A/D ports and make Port A all digital. The `PIC16F690` also has built-in comparators, which I wanted to make sure were turned off.

Clearing the `CM1CON0` and `CM1CON1` registers takes care of this. Finally, the Port C `TRIS` register is cleared to make all of the Port C output pins drive LEDs. Below, I create a variable named "LEDs" to hold the LED's display state.

The last part of the program is a simple For-Next loop that increments the variable "LEDs" from 0 to 15 and displays the value as a binary display on

the four demo board LEDs (Listing 1C).

In the middle of the For-Next loop is a `DEBUG` command line. In fact, there are two, but one is commented out. I did two of these for a purpose. The simpler one sends the state of the variable "LEDs" as a raw data value. The UART tool will display it as a hex value, if I select that button. Figure 4 shows the UART tool screen. I highlighted some of the features, including the HEX vs. ASCII selection button in the upper-right corner. The data received is shown on the left of the screen in HEX mode.

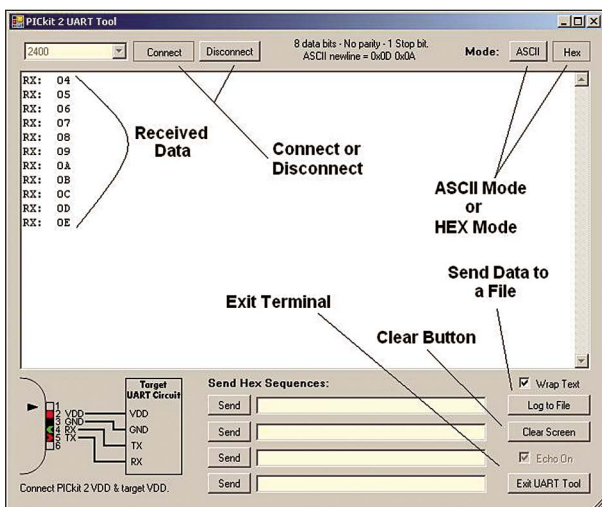
Notice how the prefix "RX:" is put in front of the data. The UART tool does this automatically. As you can see from Figure 4, the value of "LEDs" is displayed so I can monitor the variable and watch it change. Now, this data being displayed could also be a register value or a timer value, or it could simply be a special code that indicates where the program is if it suddenly starts doing something unexpected. Knowing where to look for a coding error is half the intent of in-circuit debugging.

So far, this new method of debugging was working great. Then it got better.

SENDING DATA TO EXCEL

One of the great features I discovered in this UART tool is the ability to easily store data in a file that can be loaded into Microsoft Excel. The "Log to File" button takes care of this. I didn't want the "RX:" included in the Excel file, just the data; so the second `DEBUG` command line takes care of this. That line sends the data as an ASCII character because the "#" sign is in front of the variable. I also sent a hex \$0A (new line) and \$0D (carriage return) ASCII command value, so the data is separated in a way Excel can easily understand – plus it displays nicely. Figure 5 shows the Excel file for this `DEBUG` "datalogging to file" method.

The Datalog button turns green when it is datalogging and gray when it's not. This makes it easy to control. Just clicking on the button switches it from datalog off to datalog on and back again. You have to give a name



■ FIGURE 4. UART Tool Window.

to the file created, and I chose "test.xls." By using the suffix ".xls" this allowed Excel to easily find the file and convert it to the proper format when I opened it in Excel.

Once you have this data in an Excel file, you can easily plot it and do all kinds of interesting things. Having a small MCU read a sensor and store the data into EEPROM, then — at the push of a button — dump the data out the PICKit 2 to a log file in Excel format is something that can easily be done in less than 31 commands. (Now does it seem like a big deal?)

PICBASIC PRO DEMO

I didn't mention that I compiled all this code with the new PICBASIC PRO demo code, while running it in Microchip's MPLAB IDE. This wasn't necessary, since I'm programming from the standalone version of the PICKit 2 software. You can write the code and compile it in any IDE you want, including the MCStudio version that comes with the PICBASIC PRO demo code when you download it.

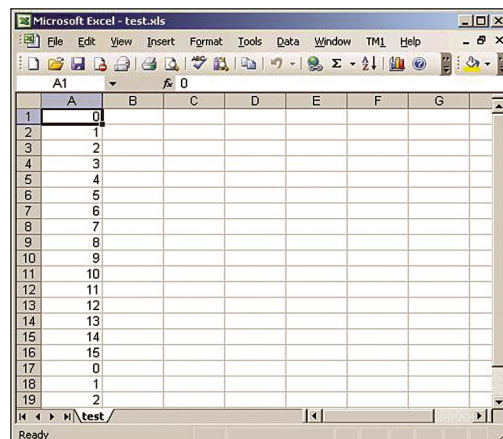
The reason I mention this is because the demo version also allows you to test running PICBASIC PRO in Microchip's MPLAB IDE and use the various features of the MPLAB IDE, including the great simulator. That's an advantage because now you can write code for a smaller PIC MCU and test it on your PC, without even hooking up hardware. Can it get any better?

By my count, I only used 16 lines of code and I could have left a few of the setup commands off if I needed more space to fit within the 31 command limit. This whole setup worked so smoothly the first time I tried it, I was driven to quickly write this up for you.

I also took Basic Micro's BasicATOM chip and programmed it to send data serially out of the same PICKit 2 pin, except that it had the 28-pin demo board connected. It also worked great with the UART tool, though I couldn't program the BasicATOM with the PICKit 2, since the BasicATOM programs itself via a bootloader. It just proved to me that the UART tool is a handy addition to the PICKit 2 programmer.

One of the reasons I used boot-

■ FIGURE 5. Excel File with Data-Logged Data.



loaders in the past for all my development was to get this type of simple interface between the PIC MCU and the PC. I often used a USB-to-RS232 adapter, so I could use a laptop without a nine-pin serial port. The PICKit 2 delivers here, again, handling the USB interface.

This demo version should now give beginners out there a great place to start small and see how much fun programming microcontrollers can be. A small investment in a PIC programmer and a few PIC MCUs plus the PICBASIC PRO demo should have you doing all kinds of simple — but effective — projects. I've received email from teachers who wanted recommendations for something beyond the \$50 module path. Now this new setup should give the student/teacher no limit on how far they can take their programming skills.

CONCLUSION

I personally and publicly want to thank the great people at microEngineering Labs for the updated demo version. After you use it, I know many will want to slide over to the full-featured version so you can program any of the smaller pin count parts; not to mention all the other PIC MCUs that the PICBASIC PRO compiler supports. I often fail to mention that microEngineering Labs has their own USB programmer, which works well with the MCStudio IDE. It also has numerous socket adapters for programming the various surface-mount packages. I find their prices on these adapters are very reasonable. If you use surface-mount packages, you might look at the microEngineering Labs' USB programmer, as well.

I'm even looking into a programming contest, using this new sample version of PICBASIC PRO — so stay tuned for more on that. I'm also plugging away on my beginner book for programming in the embedded C language, using this same programming-tool path. That was the whole point of offloading the hardware sales and

development portion of **elproducts.com** to **BeginnerElectronics.com**. I just could not keep up with it all, without something falling behind. My books were suffering, and I have too many topics I'm working on to let them slip anymore.

You can visit my site **www.elproducts.com** for updates or details about my books and articles as I post them, and please visit my friends at **BeginnerElectronics.com** to see how they are progressing. They've promised me they would continue to support the readers of this column, along with my previous customers of the boards and designs I've used (and continue to use) in my books and articles.

It's one of the things I hated when I started out. I would read about some new kit or project and then not be able to reproduce it, because the kit or some parts were not available. **BeginnerElectronics.com** promises me that this will not be an issue. Maybe I can convince them to offer a special reader discount. No promises, but I'll keep you informed.

Also, visit the **microchip.com/pickit2** site for the latest PICKit 2 downloads and demo boards. This little programmer/debugger is really something special. Keep those emails coming because, as this article proves, I listen to what you want and, when I get a chance to talk to the big shots of this industry, I will seize that opportunity. See you next month. **NV**

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■ Chuck Hellebuyck can be reached at **chuck@elproducts.com**

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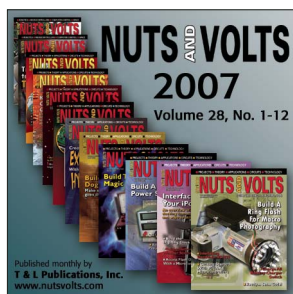
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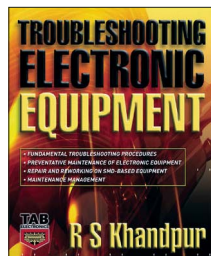
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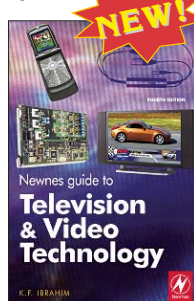
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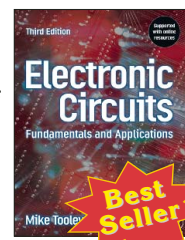
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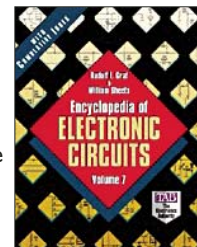
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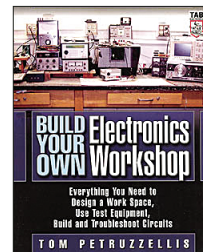


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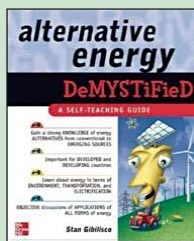


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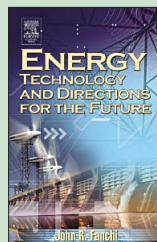
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by John R. Fanchi
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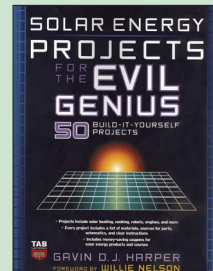
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by Gavin D. J. Harper
 Publish Date: June 22, 2007

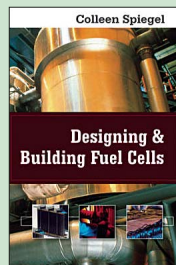
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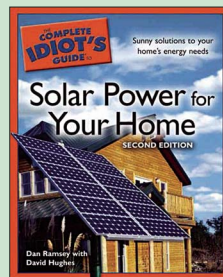
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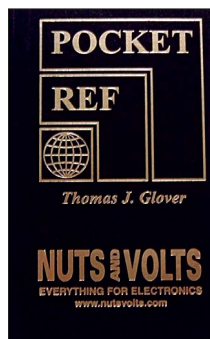
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by Brown, Damon
 Publish Date: August 7, 2007

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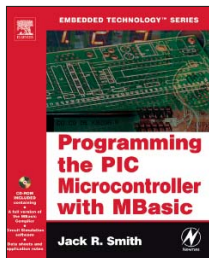


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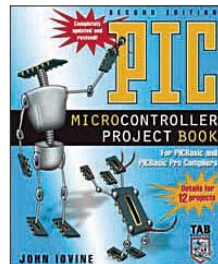
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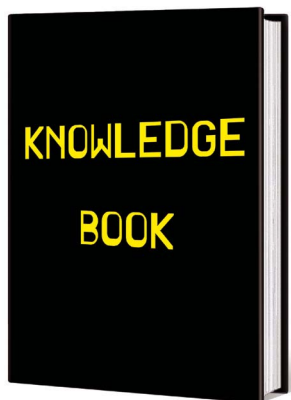
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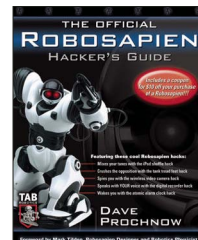


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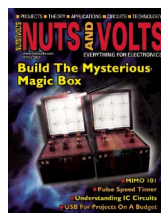
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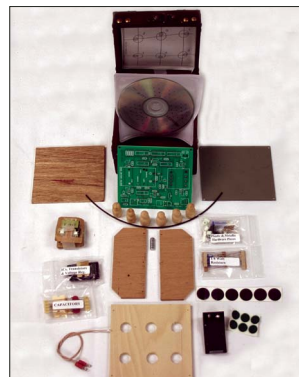


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READER FEEDBACK

Continued from page 8

read in N&V, please impress this on the editor! We would be glad, and will try our best to meet it.

For now, I have created a download link to a non-limited copy of our software free of charge. The manuals should make good reading. Hope that it is of interest: www.intricad.com/TriAngles/CAS/VIP/JamesWeikle/TriAnglesSetUp.zip.

— Dan Mauch

BENCH (IM)PRESSED

I have been interested in exploring signal processing with Excel for a long time. Your October '07 article, DFT Basics by Paul Kafig, jump-started me on this project. A similar treatment demonstrating Digital Signal Processing in the implementation of filters would be great. You continue to make my subscription to your magazine very worthwhile.

Also, I just finished building the Period Counter from your September '06 issue, after figuring out that the U13 missing from the parts list was a 74C926 and that C6 needed to be increased a little in value to make the Overflow indicator latch auto-reset reliably. I have needed a Period Counter for years to make the occasional low frequency and pulse width measurements that standard frequency counters can't do. This one works great. I would like to see more instrumentation projects like this that would be useful on the bench.

My compliments to Nuts & Volts, Paul Kafig, and Robert Reed. Thanks!

— Daryl Autrey
Oroville, CA

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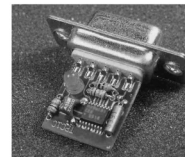
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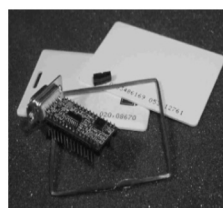
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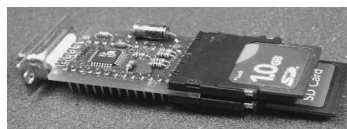


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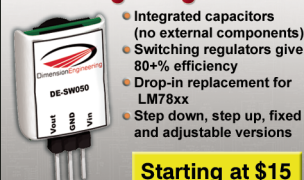
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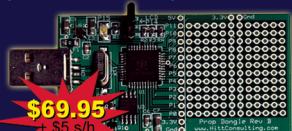
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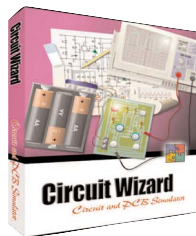
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All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams* should be computer generated and sent with your submission as an attachment.

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- ② Electronic Theory
- ③ Problem Solving
- ④ Other Similar Topics

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>>> QUESTIONS

I have seen a couple of articles on modifying an AM/FM radio to receive SW, but can't seem to get it to work. I have tried on all three of my analog tuned AM/FM radios, but to no avail.

Can someone supply a working modification? The three radios I have access to are a GPX Personal Receiver #A2094AQUA, GPX Clock Radio #D503CLR, and a BBS Cleartunes Boombox CT-330.

I have no direct access to the Internet, so I cannot do searches for the information. I can have some articles printed if I can get URLs. I also cannot simply buy an SW receiver.

#11071

via email

My mother has Alzheimer's and is unable to operate her television anymore. We had a very simple remote with about six large buttons which she could use. That TV broke and our new 37 inch LCD is a good size for her, but the remote has about 40 tiny buttons which she can't see or remember which ones to press. She occasionally had trouble with just six buttons because they were similar in shape and location.

The functions she needs are TV off/on, volume and channel up/down. I want to build a simple remote with giant buttons that are perceptually different for each of these two-dimensional

control functions in hopes that she will intuitively feel the difference.

The volume controls are most crucial and frequently used. For most programs, she needs to turn the dialog parts up, but then the action background is too loud for her and must be turned down. She used to be able to use her own remote on the old set, so I would like to fashion a programmable remote for her.

#11072

**Stan
via email**

In the past several years, it has become harder and takes greater pressure to make contact with most of the rubberized keys on our TV remote.

Inside, I've noticed a slimy film covering the circuit board and keys. I've cleaned everything with contact cleaner. It worked for several months, then, the same old problem re-appeared. Does anyone have the same problem and what did you do to solve it?

#11073

**Theodore Turk
Euclid, OH**

Is there a unit or circuit to convert HDMI to IEEE?

#11074

**Ralph Glover
via email**

Years ago, I built several "Nothing Boxes" that fascinated friends. They were boxes with six to 10 flashing ne2 lamps. They were fun to watch and

#11075 **Andrew Eliason**
Mashpee, MA

[#08071 - August 2007]

What you are seeing is the ASCII representation of the hexadecimal code that is in the file that you mentioned. This file contains data that is read and understood by the scanner and allows the user to program it.

The manual for the radio can be located at:

Additional information about this scanner can be found in a multitude of

You can also find third-party software that will help you program this radio.

[#08074 - August 2007]

I volunteer for a monkey sanctuary in Gainesville, FL, and we are looking for a monitoring system to make sure there is always heat for the monkeys during the winter months. The main source of heat is about 70 ceramic chick heaters rated from 250 to 750 watts each.

Would it be possible to design a system that uses a thermal or current sensor at each heater that could be polled via the power line? If any station went out of limits for more than 30 minutes, it should produce an alarm at a central data acquisition microprocessor or computer. The 120V electricity to the heaters is delivered through a maze of circuit breaker boxes and GFCIs supplied from at least three power meters. A ground wire is provided on all wiring.

The circuit in Figure 1 will sound an alarm approximately 30 minutes after any of the 70 thermal switches cool. Thermal switches (such as All Electronics CAT# THSW-105) that open when hot are used to hold a 30 minute timer reset. The 555 timing is set at approximately three minutes by R1, R2, and C2. As long as all of the

To keep expense down and for maximum reliability, the switches (S1 .. S70) should be connected to the circuit at the central monitoring point by wires. Polling via the power line will fail if a GFCI trips or if there is a power failure.

Ed Schick
Harrison, NY

[#08072 - August 2007]

I am wondering where I might find reprogrammable microcontrollers in common usage in everyday household life, that can be removed and reused.

#1 Most of the time, the microcontrollers are not reprogrammable in



household devices, or not entirely reprogrammable. But if you look in a lot of things and can recognize a microcontroller, then you are more likely to find them. Older PCs have 8042, 8048, or 8051 microcontrollers in them both on the motherboard and in the keyboard. They may be reprogrammable. If they are semi-reprogrammable — as is usually the case — they can be connected to external program memory, which a typical example of is the BIOS Flash or EPROM chip. The microcontrollers I mentioned are Intel's most popular chips, far exceeding Pentiums. And the 8051 has a lot of variations such as 8052, 8055, 8751, 8752, 8052AH, 8951, 8952, and many others. Don't overlook the ones with a C in the middle of the number.

The 87xx and 89xx are generally totally reprogrammable except for "OTP" type 87xx chips. Especially if the "7" chip has a window like an EPROM. Phillips and Atmel make reprogrammable chips that are becoming more common, including 89xx. Atmel makes AVR's (90xx), found in some moderately priced devices. Reprogrammable Microchip PICs are still rare to find in junk. One clue to a reprogrammable chip is if its device is remotely updateable, such as in set-top-boxes, DVRs, etc.; although

those tend to be highly inconvenient to tamper with. If you find obsolete ones in a dumpster and local law permits, get a desoldering gun and heat gun and recycle those chips! Disassemble all your broken peripherals; you never know if there's an AVR in your mouse or printer. Another place I've found many used controllers is in business phone systems, so watch for those in dumpsters, too. In the phones and in the PBX or KSU, as well. You might find HC11s in printers, scanners, VCRs, maybe even TVs.

Maybe you'll find Hitachi 6303s which are programmable with an HC11 assembler as long as you are aware of what instructions and features are missing in them.

Similar is the MC68701 and MC6803, and HD63701.

If a device is or used to be "smart" and digital, there's some kind of microcontroller.

A Z-80 can't do much by itself, but a few other chips grow a computer, so you might want to save eight-bit processors (including 6502, 6809) as well, and interface chips such as 8755 or 6520, 6522, 6821, 6822, and EPROMs and static RAM.

Conclusion: Scavenge ALL your junk like a vulture before you dump it!

William Como
Bethpage, NY

#2 In this day and age, when most of the common household appliances are programmable and have a digital display in the form of LEDs or LCDs, they incorporate microcontrollers to facilitate this function. Just looking around my house, I found the microwave oven, the cordless phone, DVD player, etc., that use microcontrollers.

However, this does not mean that one will be able to use them for projects. Some of the microcontrollers that are inside these appliances are ASICs (Application Specific Integrated Circuits), that is microcontrollers that have been developed by the manufacturers of the appliances in order to save costs when using them in large numbers. The public does not have access to the documentation of such devices. Even when they are third-party microcontrollers, they may be obscure and relatively obsolete parts that may not fit your needs. Finally, there is the problem of desoldering these parts without thermal damage or physical damage to the pins.

So, although it can be theoretically done, it will be a hard task with low chances of success. On the other hand, microcontrollers from PIC, AVR, and others are readily available these days for a couple of dollars. They also have all the documentation needed online, making them the preferred choice for projects that will not run hundreds of thousands of units.

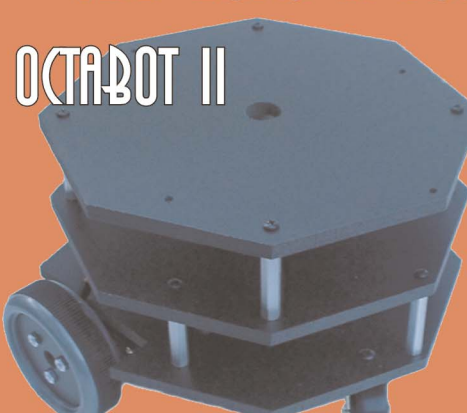
Albert Lozano
Shavertown, PA

[#09071 - September 2007]

I am looking for a specific recommendation of hardware and software within the PIC, BASIC Stamp, etc., single board microprocessor products that will allow me to trigger (i.e., send an ASCII string) and then take the continuous output from an electronic gauge via RS-232 and display it on an LCD screen.

#1 A Stamp PLC would be an excellent choice. I use a Stamp PLC to monitor a hygrometer (4-20 mA) and Hastings vacuum gauge (RS-232), and control solenoid valves. This equipment is part of a test station that

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For a user interface, I would use VB.NET 2005 or VB6. The 2003 version of .NET didn't include the RS-232 control.

The Stamp PLC comes with excellent example code for configuring the A/D and I have found it to be very reliable. In fact, I use Stamps all over our manufacturing facility.

Jeremy Jackson
Fort Wayne, IN

#2 As it happens, I just finished something similar myself. It sounds as if you might be just starting out. If so, I recommend beginning with something that will give you quick results and easy success. In this case, consider using the Parallax Board of Education full kit (Stock#: 910-28103, http://parallax.com/detail.asp?product_id=910-28103). When you get done with this experiment, this configuration will serve you well for lots of other experiments, too.

Interfacing the BS2 (BASIC Stamp 2) with a standard Hitachi HD44780 LCD display is quite easy. The documentation and sample code they have for interfacing their Sensirion Temperature/Humidity Sensor (stock #28018) to an LCD gives you plenty to get you started. They even have an HD44780 display if you do not already have one. The BS2 has built-in RS-232 capabilities that should make this a snap.

Bob Hyland
Trumbull, CT

#3 Selecting a microcontroller (uC) is certainly frustrating. Beyond the hardware IC, there are many things that can trip the beginner. At a minimum, you'll need a programmer for the specific chip, a PC to run software development programs and the programmer, and target hardware that includes a power supply and any specific interface for your application.

The easiest way to get past this hurdle is to buy a ready-made product. What you buy depends on your comfort level and budget, but it also depends on what you are trying to get out of the first project. The two most popular uC chip families are PIC (Microchip) and AVR (Atmel); there are other uCs, but these two particular ones have a mountain of help and advice online.

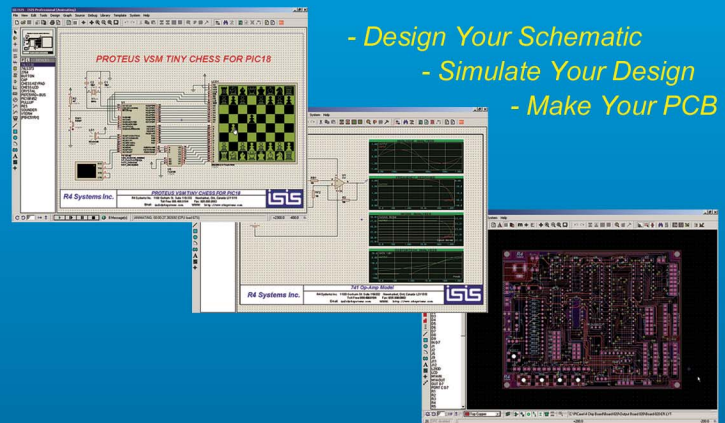
If you are engaged with a larger project and just need this piece to get data from the gauge and move onto another problem, I'd strongly suggest buying an all-in-one uC development system that can be quickly installed and jump right into programming. For the PIC family, take a look at MELabs bundled systems (they advertise in *Nuts & Volts*). For the Atmel AVR devices, consider the STK500 Starter Kit for under \$100 available from Mouser and others.

If you are on a very tight budget or want to know a lot more about the uC world beyond this gauge project, then buying a few uC chips, a barebones programmer that runs from a PC, and downloading free or shareware development programs to write code is the way to go. This is a much steeper but rewarding learning curve.

Peter Stonard
Campbell, CA

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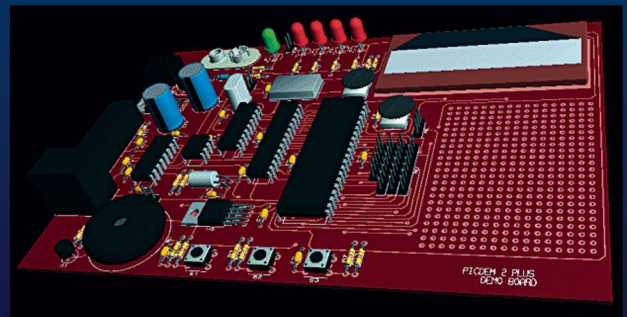
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IN THE SPOTLIGHT



An Interview with Mark Walsh

Director of Marketing and Product Development, MCM Electronics

by Marvin Mallon

This month's spotlight is on MCM Electronics, a division of Premier Farnell. The multi-national organization is a publicly held company listed on the London Stock Exchange. Formed in 1996, Premier Farnell is a global, business-to-business, small order, high service distributor of electronic components and industrial products to the design, maintenance, and engineering sectors. They are a Public Limited Company headquartered in Great Britain. MCM has been a part of this organization for close to 10 years, though it had been founded over 30 years ago. Their main offices are located in Centerville, OH and their distribution center and showroom is in nearby Springboro. Both facilities are just a few miles south of Dayton and are operated by 130 employees. The principal marketing and advertising officers of MCM are Mark Walsh, whose responsibility extends to marketing and product development and Terry Carity, another senior member, handles advertising. When interviewed for this column, Mark responded to our questions as follows:

Marvin: When was MCM founded?

Mark: MCM was founded over 30 years ago. MCM, believe it or not, started as a radio/television repair company. The owner at that time was having difficulty finding the service parts needed for repairs, so he started sourcing the parts himself. He found that he could make more money distributing service parts rather than complete the actual repairs himself.

Marvin: What is your and Terry's background in this business?

Mark: I'm the Director of Marketing and Product Development for MCM and have been with MCM for over 12 years including positions in purchasing,

product development, and marketing. I graduated from Bowling Green State University with a dual degree in business. Terry Carity is the Director of Advertising for MCM. He has been with MCM for over 20 years and has been promoted several times to his current position. He graduated from Sinclair Community College with a degree in Commercial Art.

Marvin: How large is your main distribution center?

Mark: MCM's corporate headquarters is located in Centerville, OH. Our state-of-the-art distribution center is located approximately 10 miles south of Centerville in Springboro. Our distribution center is approximately 140,000 square feet. MCM's expanded showroom allows local customers to call in their orders for quick and convenient order pick-up.

Marvin: How would you describe your principal activities at these locations?

Mark: MCM is a broad line electronics distributor serving the consumer repair, home integration, gaming, and education market. We stock over 40,000 products including audio/video service parts and accessories, test equipment, professional and home audio products, security equipment, tools and tech aids, wire and cable, and a whole lot more. MCM also has access to over 1.5 million electronic parts and related products from other Premier Farnell divisions.

Marvin: What segment of your products would you say is the most popular?

Mark: The Tenma test and soldering equipment line is one of MCM's most popular product lines. For over 25 years, Tenma has maintained a reputation of exceptional quality soldering and test equipment at a very reasonable price.

Tenma multimeters, power supplies, oscilloscopes, pattern generators, and counters are recognized worldwide, and have become staples in the service and manufacturing industry and with security, audio, CATV, and SATV installers.

Marvin: Is there a newly developed product ready for release?

Mark: Yes, MCM recently introduced a speaker measurement interface. The Tenma SMI is essential for design, refurbishing, or do-it-yourself speaker building. This compact interface is powered directly from the USB port of most PCs, including laptops, and provides full measurement parameters of the connected speaker. When connected to an unmounted speaker, this device measures all needed parameters to accurately design a perfectly tuned enclosure. Measurements can be performed in most any shop or home; no special microphones or testing area is required.

Marvin: Can you summarize your company's mission and its policies?

Mark: MCM stocks products to test, repair, upgrade, and/or install consumer electronics. We make it very easy for the customer to order electronic products using a multi-channel approach. A customer can call in their order to our friendly call center, order from our fantastic website, and local customers can pick up their orders from our recently expanded showroom. **NV**



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- Ceramic heating element for more accurate temp control
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Protek

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> Soldering & Rework > Hot Air Rework

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- Stepped Current: 30mA +/- 1mA
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GDS-2062	60MHz, 2Ch DSO	\$890.00
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GDS-2102	100MHz, 2Ch DSO	\$1160.00
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Convert any PC with USB interface to a high performance Digital Storage Oscilloscope. This is a sophisticated PC basedscope adaptor providing performance compatible to mid/high level stand alone products costing much more! Comes with two probes.

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\$12.25
Quantity
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Item# PM-128E

Additional Panel Meters on Web Site!

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Item# PM-1028A

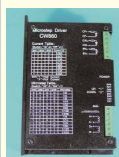
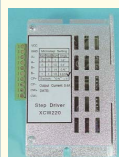
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Stepper Motors

Part #:	Motor Frame Size:	Holding Torque:	Price:
42BYGH404	NEMA 17	3.4kg.cm/47oz.in	\$17.95
57BYGH207	NEMA 23	8kg.cm/111oz.in	\$24.95
57BYGH303	NEMA 23	15kg.cm/208oz.in	\$29.95
57BYGH405	NEMA 23	20kg.cm/277oz.in	\$34.95
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85BYGH350C-03	NEMA 34	63kg.cm/874oz.in	\$119.95



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XCW220	100mm x 61mm x 19mm	1(200), 1/2(400), 1/4(800), 1/8(1600)	\$39.95
CW220	99mm x 65mm x 30mm	1/2(400), 1/8(1600)	\$49.95
CW230	115mm x 72mm x 32mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800)	\$59.95
CW250	140mm x 94mm x 45mm	1(200), 1/2(400), 1/8(1600)	\$69.95
CW860	147mm x 97mm x 30mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800), 1/128(25600), 1/5(1000), 1/10(2000), 1/25(5000), 1/50(10000), 1/125(25000), 1/250(50000)	\$119.95

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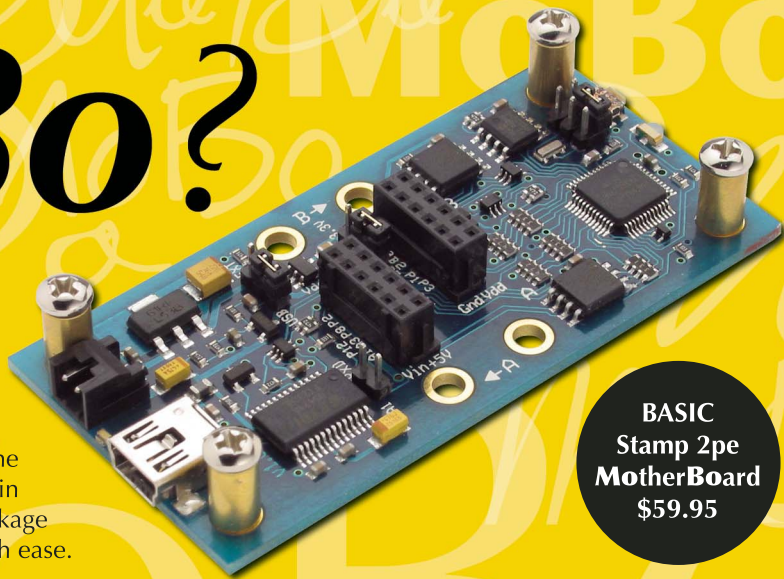


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